MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

VOL. 51, No. 12.
W. B. No. 825.

DECEMBER, 1923.

CLOSED Feb. 2, 1924.
ISSUED Mar. 10, 1924.

DAMAGING TEMPERATURES AND ORCHARD HEATING IN THE ROGUE RIVER VALLEY, OREG.

By FLOYD D. YOUNG, Meteorologist, and CLAUDE C. CATE, Plant Pathologist.

[Weather Bureau, Los Angeles, Calif., Oct. 25, 1923.]

INTRODUCTION.

There is a growing tendency on the part of fruit growers and others engaged in agriculture to demand a practical demonstration of the value or correctness of any information or new method connected with their work which varies from their established practice. This is especially true of orchard heating and temperatures which cause damage to fruit blossoms. The tendency at present is away from laboratory experiments and toward the summing up of results observed in actual practice.

The work on which this report is based was begun by the United States Weather Bureau with the primary objects of studying in detail all the different phases of orchard heating and of developing new and more accurate methods of predicting low temperatures. In order to carry on this work it was necessary to obtain very accurate continuous records of the temperature throughout the frosty nights of spring, made with special thermographs, in several different orchards in the Rogue River Valley, in southern Oregon. Since these records were available, it occurred to the writers that they could be used in connection with observations of the amount of damage to fruit following each frost, to give some information regarding the temperatures which cause damage to fruit at different stages of advancement.

Since the pear is the principal fruit crop of the valley, the greater number of observations have been made on this fruit. It appears that comparatively little work has been done to determine temperatures which cause damage to pears; much more information is available regarding critical temperatures for peaches, apples, and apricots.

The latter part of this article is given over to a discussion of the practical value of orchard heating in the Rogue River Valley, and to actual comparisons of the pear crops harvested from adjoining protected and unprotected orchards during the 1921 and 1922 seasons.

DESCRIPTION OF INSTRUMENTS AND EXPOSURES.

It is well known that any object exposed to a clear sky at night will lose heat by radiation to the sky, until its temperature is lower than the temperature of the surrounding air. This is true of a thermometer which is not sheltered from the sky, and is also true of the outer leaves, fruit or blossoms on a tree. For this reason it is often suggested that in determining temperatures which cause damage, an unsheltered thermometer should be used.

There are other matters, however, which must be considered in this connection. Different substances do not radiate heat at the same rate. In general, dark-colored objects radiate heat more rapidly than light-colored objects. Therefore it would not be correct to assume that an exposed alcohol or mercurial thermometer, mounted on a metal back, will indicate correctly the temperature of the green leaves or the white blossoms of the pear tree.

The lower portion of the tree is usually more or less screened from the sky by adjoining trees, and blossoms or fruit in the interior of the tree are almost completely screened by the leaves, branches, and fruit above. The most exposed portion of the tree, and the portion cooled most by radiation to the sky, is the top, and this cooling is nearly always more than offset by the difference in air temperature between the top and bottom of the tree, due to the layer of cold air near the ground.

The object in sheltering a thermometer is to eliminate, so far as possible, the effects of loss of heat by radiation, and to obtain, as nearly as possible, the actual temperature of the air. As a matter of fact, however, the air inside an instrument shelter is usually somewhat colder than that outside the shelter on a clear, calm night, due to the cooling of the shelter itself by radiation to the sky.

It is impracticable to obtain records of the actual temperature of blossoms or fruit on trees in the orchard. The rate of loss of heat by radiation to a clear sky, other factors being the same, depends on the amount of moisture in the air. If the approximate amount of moisture in the air is known, together with other conditions of radiation, an allowance might be made for the cooling of the blossoms or fruit below the air temperature or that registered inside the instrument shelter.

Other sources of error are introduced when an exposed thermometer is used, so that it seems best to use temperatures secured inside a well-ventilated shelter, together with observations of the amount of moisture in the air, in preference to unsheltered thermometer readings, in determining the temperatures which cause damage.

All temperatures shown in this article were secured inside "fruit-region" instrument shelters. (See fig. 1.) These shelters were specially designed for fruit-frost investigational work, by the Instrument Division of the Weather Bureau, to allow a freer circulation of air than in the older designs. Thermometers were 4½ feet above the ground. Thermograph records were usually checked at frequent intervals during the night, so that they are accurate within a few tenths of a degree as a general rule.

Instrument shelters were placed in the center of the intersection of two tree rows. Damage estimates were made from counts of damaged blossoms or fruits from the four trees immediately surrounding the instrument shelter. Positive indication of damage was required before a blossom was counted as injured. Those showing only slight discoloration were counted as uninjured.

From 150 to 350 blossoms were cut open and examined in determining percentages of damage at each count.

DESCRIPTION OF VALLEY.

The portion of the Rogue River Valley in which the studies described in the following pages were made, is about 20 miles long, with an average width of about 6 miles. It is walled in on the south, east, and west by mountains, and narrows down to a gap through which the river flows on the north. The slope of the floor of the valley is from south to north. Freezes, accompanied by strong winds, are practically unknown, although a light wind from a southerly direction is nearly always noted on a frosty night.

Generally speaking, the orchards are exceptionally well cared for, and nearly all the fruit growers attempt to produce high grade fruit. A great many different types of soil are found in the valley. Few growers apply fertilizer of any kind to their trees, although cover crops are grown quite generally. Orchards extend from high up on the hillsides down to some of the lowest ground on the valley floor. Practically none of the orchards on the hillsides are equipped with orchard heaters.

OBSERVATIONS DURING 1919 SEASON.

The weather as a whole during the 1919 season was about normal, and the trees bloomed about the usual time in the spring. Heavy frosts were confined to the colder spots on the low ground; there was no damage by frost to any fruit located on the slopes.

The temperature records shown in Figures 3 and 8 were obtained in two orchards a short distance apart, in one of the coldest spots in the valley. The temperature stations were placed in spots where the records were practically identical when there was no artificial frost protection. One station was located in a pear orchard equipped with 5-quart lard-pail oil heaters and the other was in an adjoining pear and apple orchard not equipped with heaters. The age of the trees in the fired orchard was 19 years; and at the check station the ages were: Winter Nelis 25 years, Howell, Bartlett and Anjou, 15 years, Newtown apples 20 years. The soil at both stations was clay adobe, and the orchard care was excellent. The following specific comments may be made with reference to the several diagrams:

Figure 3—Damage to blossoms.—Evening dew point 33° F. Check station (unprotected): Newtown apple buds not yet showing pink; Winter Nelis pear buds showing pink; no damage to either by frost. Fired orchard: Bartlett, Clairgeau, and Anjou approaching full bloom. No damage.

Figure 4—Damage to blossoms.—Evening dew point 30° F. Check station (unprotected): Newtown apple buds not yet showing pink; Winter Nelis pear buds showing pink. No damage to either by frost. Fired orchard: Anjou and Howell pear trees in bloom; Bosc, Winter Nelis and Comice buds showing pink. No damage to any variety near station on this night. No damage could be found in the entire valley following this frost, even where no orchard heating was done. Banks of clouds gathered on the eastern horizon just before sunrise, and direct sunlight did not strike trees until two or three hours later.

Figure 5—Damage to blossoms.—Evening dew point 27°. Anjou, Bartlett and Howell pear trees in full bloom; Bosc within two days of full bloom; Nelis and Comice about four days before full bloom. Newtown apple buds showing pink. Check station (unprotected): Newtown apple buds not damaged. Winter Nelis pear buds not damaged. Anjou and Howell pear blossoms show 25 per cent damage. Fired orchard: No damage to Howell, Anjou, Clairgeau, Bartlett, Bosc, Comice, or Winter Nelis pear blossoms or buds. No clouds in sky after sunrise.

Figure 6—Damage to buds and blossoms.—Evening dew point 32°. Bartlett, Howell, Anjou pear trees in full bloom; Clairgeau pear trees within two days before full bloom; Winter Nelis within three days of full bloom; Bosc and Comice about four days before full bloom. Newtown apple buds in late pink stage. Check station (unprotected): Newtown apple buds show 4 per cent damage. No evidence of any damage found in Winter Nelis pear buds. Bartlett blossoms show 52 per cent injury, mostly in earlier bloom. Howell pear blossoms show 67 per cent injury. Fired orchard: No damage to Howell, Anjou, Clairgeau, or Bartlett blossoms, or to Bosc, Comice or Winter Nelis buds.

Figure 7—Damage to fruit.—Evening dew point 35° Photographs (figs. 10 and 11) show stage of development of different varieties of pears, and of Newtown apples. It was not possible to check on the amount of damage on the following day, and as another frost occurred on the night of May 4–5, the damage on these two nights was checked together. See Figure 8 for damage estimates.

Figure 8—Damage to fruit.—Evening dew point 31°. Photographs (figs. 10 and 11) show stage of advancement of Newtown apples and different varieties of pears. Following records of damage include damage done on previous night. (See fig. 7). Check station (unprotected): Newtown apples in lower half of trees show 85 per cent badly discolored, and a small proportion of the remaining 15 per cent slightly discolored. Nearly all of the larger fruits badly discolored; uninjured fruits practically all small. In upper half of trees, where the average lowest temperature for 45 minutes was 29.8°, from 45 to 50 per cent of the fruits showed discoloration. Winter Nelis pears in lower half of trees showed 65 per cent badly discolored and 30 per cent slightly discolored. In upper half of trees from 35 to 40 per cent of the fruits were discolored. All of this damage was done on the nights of May 3–4 and 4–5, as blossoms damaged in previous frosts had fallen from the trees some time previously. Fired orchard: No damage to Howells, Anjou, Clairgeau, Bartlett, Bosc, Comice, or Winter Nelis pears in immediate vicinity of temperature station. In portion of orchard fired last, Bartlett pears had already begun to blister badly, indicating that critical temperature had been reached.

It will be noted that on the night of April 13–14, (fig. 6) Winter Nelis pear buds, within two days of full bloom, withstood a temperature of 26° F. or below for one hour, with a minimum temperature of 25° F., without injury.

Six days later, on the night of April 19–20, when the trees were slightly past full bloom but the petals had not been shed, a temperature of 30° F. for 30 minutes caused about 17 per cent damage. This variety of pear tree practically always carries a heavy bloom, and so small a loss would have no effect on the final crop.

On the night of May 4–5, (fig. 8) when the petals had been shed and the fruits were about one-fourth inch in diameter, a temperature of 27° F. for about one hour caused 65 per cent of the fruit on the lower half of the trees to show deep discoloration and about 30 per cent more showed slight discoloration. Near the tops of the trees, where the average lowest temperature for 45

FIG. 1.—Fruit region instrument shelter in which temperature records were obtained.

FIG. 2.—Pear orchard equipped with 250 2-gallon lard-pail oil heaters to the acre.

FIG. 9.—Stage of development of pears, blossoms, and fruits on April 21, 1919. Left, Comice; right, Winter Nelis; upper, Bartlett; lower, Anjou.

FIG. 10.—Stage of development of pears on May 4, 1919. Upper left, Anjou; lower left, Comice; upper right, Winter Nelis; lower right, Bartlett.

FIG. 11.—Stage of development of fruit on May 5, 1919. Lower right and left, Newtown apples; upper right and left, Winter Nelis pears.

(To face p. 619.)

FIG. 17.—Stage of advancement of Bartlett and Bosc pears on May 3, 1921.

FIG. 31.—Comice pear trees shown in Figure 30, showing distribution of crop in 1922 when the orchard was protected with orchard heaters.

FIG. 30.—One of the many acres of Comice pear trees which carried a heavy crop of fruit near their tops, with very little fruit in the lower portions, in 1921, due to stratification of the air on frosty nights.

FIG. 32.—Stage of development of pear buds on April 17, 1922. Left to right, Anjou, Bartlett, Anjou. Two clusters of each are shown representative of the greatest—and least—developed blossoms.

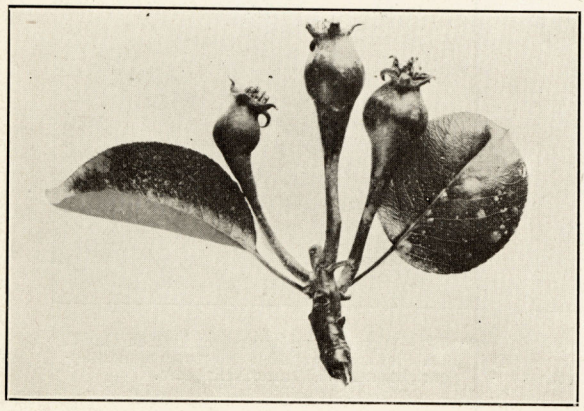

FIG. 34.—Stage of Bartlett pears on May 27, 1922. Several acres of fruits in this stage were frozen almost to the core on the morning of May 27. Practically all of them recovered completely, without marking or other indication of injury.

FIG. 33.—Stage of development of pears on April 20, 1922. Left to right: Anjou, Bosc Bartlett.

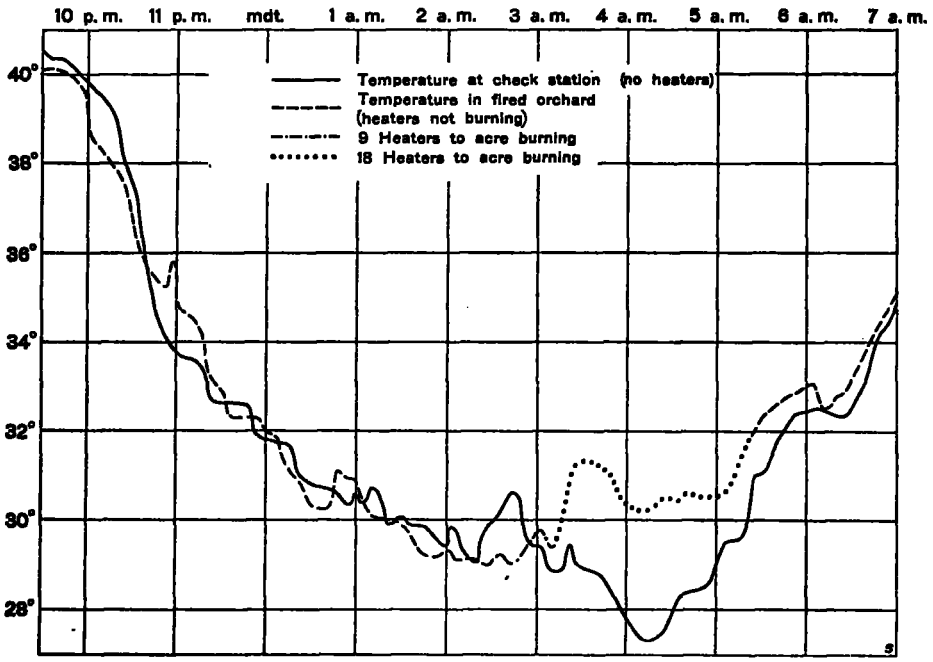

FIG. 3.—Temperature records in fired orchard and at outside check station on night of April 6–7, 1919. Temperature raised 2½° F. by using 18 heaters to the acre.

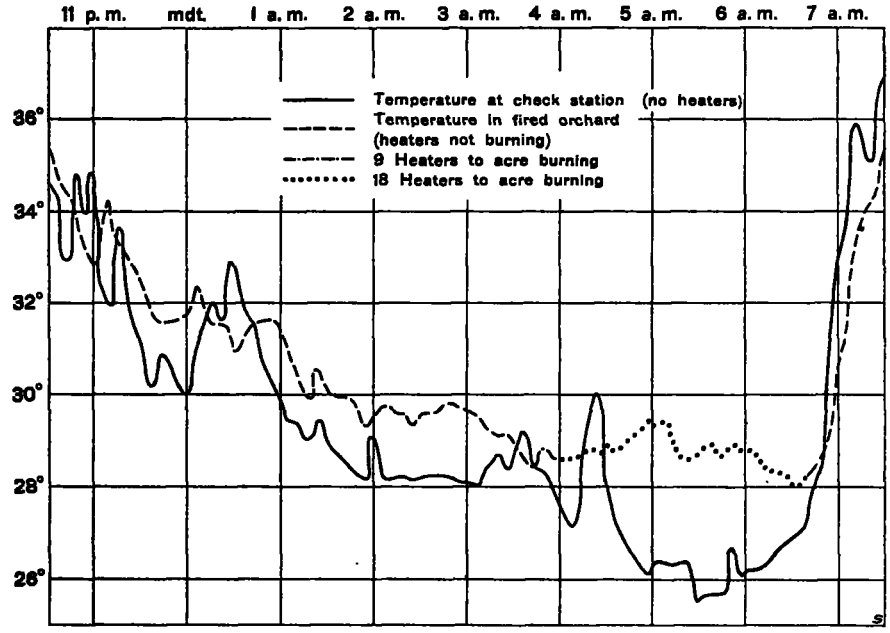

FIG. 4.—Temperature records in fired orchard and at outside check station on night of April 7–8, 1919. Results of firing about the same as on previous night shown in figure 3.

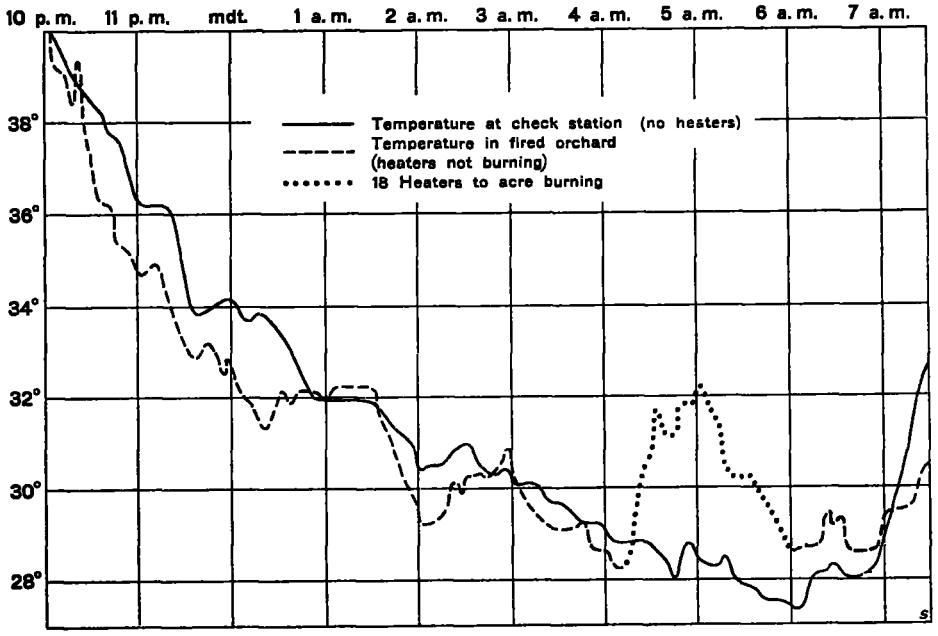

FIG. 5.—Temperature records in fired orchard and at outside check station on night of April 10–11, 1919. Heaters burning very low and beginning to go out after 5 a. m.

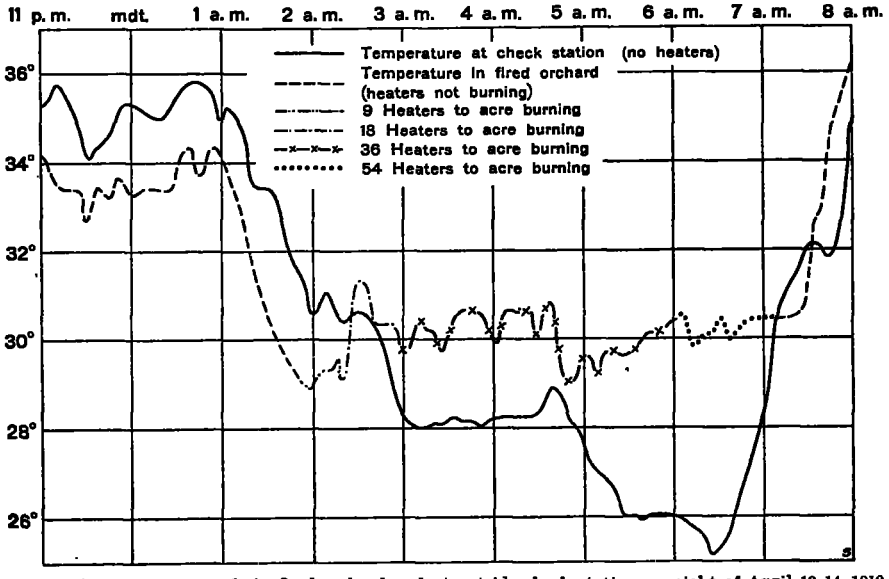

FIG. 6.—Temperature records in fired orchard and at outside check station on night of April 13–14, 1919. First lighting of heaters burning out at 4.40 a. m., caused temperature to fall. Temperature inside heated orchard held five or six degrees above outside temperature.

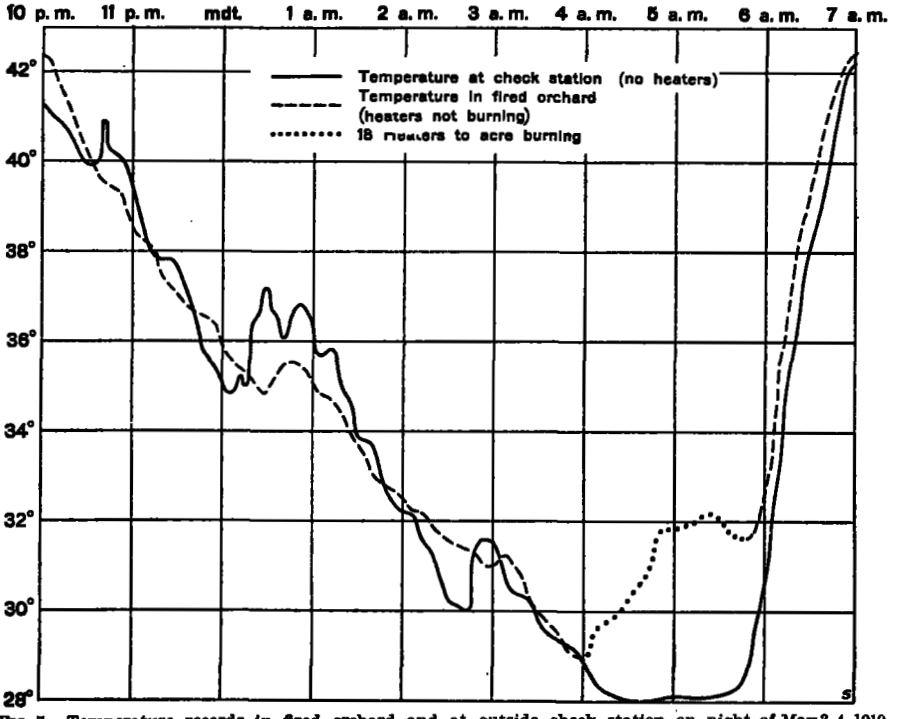

FIG. 7.—Temperature records in fired orchard and at outside check station on night of May 3–4, 1919. Temperature was raised about 4° F. by using 18 heaters to the acre.

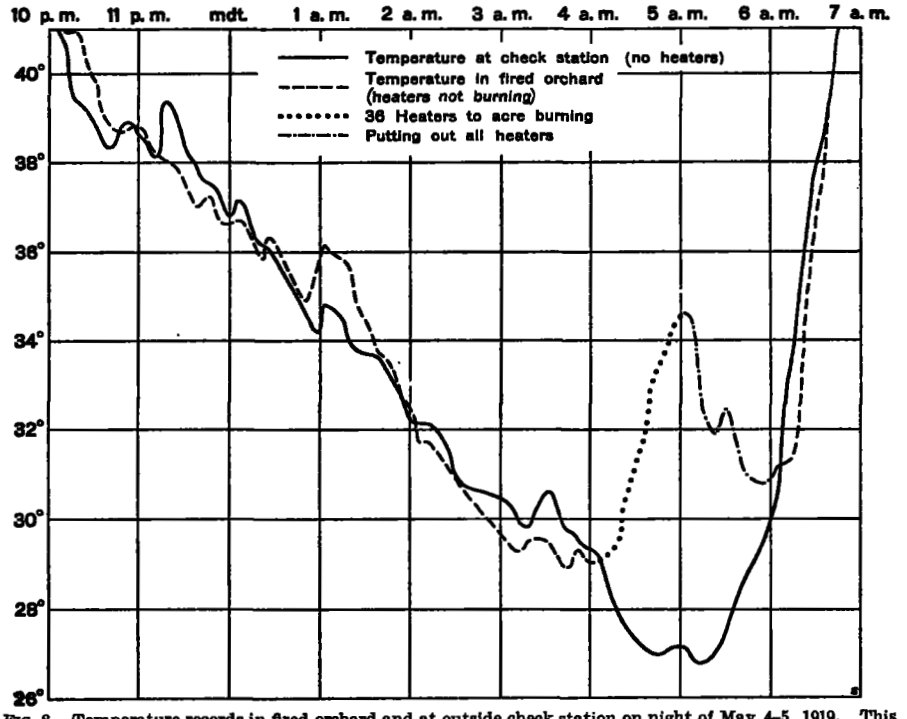

FIG. 8.—Temperature records in fired orchard and at outside check station on night of May 4–5, 1919. This was the most remarkable rise in temperature ever observed in the orchard-heating investigations of the Weather Bureau. Temperature rose 7½° F. with 36 heaters to the acre burning. Weather conditions were almost idea lfor this work. Compare with figure 6.

minutes was 29.8°, the damage amounted to from 35 to 40 per cent.

Small fruits or Yellow Newtown apple trees at the same location, slightly less advanced than the Winter Nelis fruits on this date, showed 85 per cent damage on the day following the frost. Fortunately for the grower, the trees had an exceptionally heavy set of fruit, and the final crop was not much affected. If the same percentage of damage had occurred during a season with light setting of fruit, the effect on the size of the final crop would have been serious.

On May 10, 1919, a careful examination of the fruit on the trees surrounding the check station instrument shelter was made. The results are shown in the paragraphs below. They should be considered in connection with the temperature records shown in Figures 3 to 8.

Howell pears.—All fruits the size of small marbles or slightly larger. Out of 44 fruits picked from the lower part of the trees, within reach of the ground, 42 were badly discolored and entirely seedless. Out of 14 fruits on the east side of the trees, 8 feet above the ground, 12 were badly discolored and seedless. Six fruits picked from east side of the same trees, 10 feet above the ground, were all badly discolored and seedless. On the west side of the trees, near the ground, three out of four fruits were discolored and seedless.

Anjou pears.—The percentage of injury shown by Anjou pears at the check station was about the same as shown by the Howell.

Winter Nelis pears.—Out of 38 fruits nearest the ground, 30 were discolored. Out of 15 fruits picked at a height of 7 feet above the ground, 10 were discolored. At a height of 10 feet above the ground, only 3 out of 12 pears showed discoloration.

Yellow Newtown apples.—Out of 63 fruits picked within a height of 8 feet above the ground, not one was found which did not show deep discoloration. Out of 15 fruits picked at a height of 10 feet above the ground, 9 showed discoloration. At a height of 12 feet above the ground, 18 out of 25 fruits showed serious damage. In the very tops of the trees, at a height of about 25 feet above the ground, only one out of 11 fruits showed injury.

At the time these observations were made all the varieties of pears examined showed no outward evidence of frost damage, except frost marks and odd shapes in the Anjou. All the fruits appeared to be growing rapidly and were of good color. The seed cavities of the injured fruits were dark brown or black and contained no seeds.

A large proportion of the apples examined, especially in the lower portion of the trees, were quite altered in shape, and contained no seeds.

No damaged, misshaped, or frost-marked fruits could be found at this time in Anjou, Bartlett, Bosc, Clairgeau, Comice, or Winter Nelis trees near the temperature station inside the fired orchard.

EFFECT OF FROST DAMAGE ON FINAL CROPS OF FRUIT AT CHECK STATION.

Howell.—About 5 per cent of a normal crop remained on the trees at picking time and about 90 per cent of this fruit was seedless.

Anjou.—About 15 per cent of a normal crop remained on the trees at picking time.

Winter Nelis.—About 60 per cent of a full crop was harvested.

Yellow Newtown apples.—At the end of the season the Yellow Newtown apple trees nearly all bore a full crop of fruit and most of them were heavily thinned artificially. In a few cases there seemed to be a heavier crop in the upper portion of the trees than near the ground, but in most cases the crop appeared to be well distributed. There was a great deal of seedless and misshapen fruit, due to frost injury, but as much of this as possible was removed by the thinners, so that the percentage of culls at picking time, due to frost injury, was not large.

OBSERVATIONS DURING THE 1921 SEASON.

During the winter of 1919–20 an unprecedented cold wave caused considerable winter injury to fruit trees in the Rogue River Valley, and it was thought observations of the effect of frosts of varying degree in damaging the blossoms and young fruit during the spring of 1920 would not be of much value because of the possible weakened condition of the trees. As a matter of fact, the winter injury was much less severe than it appeared to be at first, and most pear and apple trees bore full crops.

For about 10 days before the first frost in the spring of 1921 the sky was clear and the afternoons warm, the temperature rising above 70° F. on several dates. Fruit trees came into bloom rapidly. On April 2 a cold rain began, and on the morning of the 3d, the hills were covered with snow. Heavy snow squalls alternated with periods of clear sky and bright sunshine during the day, until about 4 p. m., when a heavy snow squall set in, lasting until nearly 7 p. m. Another snow squall passed over about 8:30 p. m. The sky cleared completely before midnight, and remained clear during the remainder of the night.

The earlier varieties of pears were in full bloom at this time. The wet snow clung to the branches and blossoms in the early evening, but later most of it melted slowly, after which the water froze, encasing the blossoms in ice. Most of the fruit growers labored under the delusion that the blossoms could not be injured, so long as they were covered with ice or snow, no matter how low the temperature fell. This belief prevented the firing of many orchards which were equipped with orchard heaters. Some growers believed they might even cause greater injury by firing, through melting the snow and "cooking" the blossoms. Orchard heaters were lighted in only two or three orchards in the district on this night, and these orchards harvested about the only perfect crops of fruit at the end of the season.

Figures 12 and 18 show that the temperature was below the freezing point for about 14 consecutive hours, with a minimum temperature below 22° F. The records of the damage caused by this freeze are exceptionally interesting, in that some varieties which were in full bloom at this time carried from 85 to 90 per cent of a full crop at the end of the season. This was true only of orchards which were adequately protected from damage by later frosts.

It is possible that the ice and snow covering the blossoms may have afforded some slight protection, by causing a slow thawing in the morning, but it is not likely that this factor had much weight in determining the amount of damage.

The temperature records shown in Figures 12 to 16 were secured at the same locations as the records shown in Figures 3 to 8. The orchard in which one of the stations was located contained 150 five-quart lard-pail oil orchard heaters to the acre. The check station was

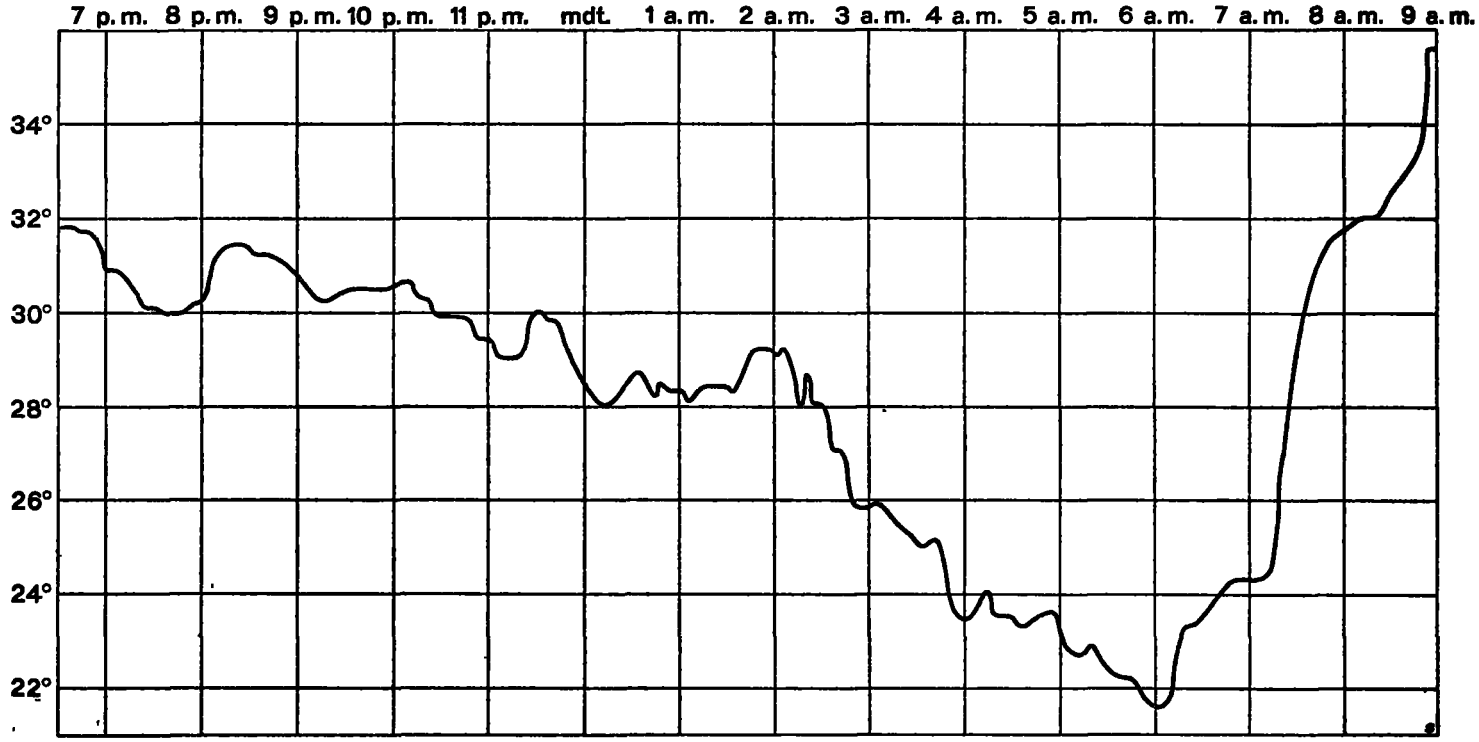

FIG. 12.—Temperature record at check station unprotected (adjoining orchard) on night of April 3–4, 1921. No heaters were lighted on this night, and temperature records at the two places were practically identical.

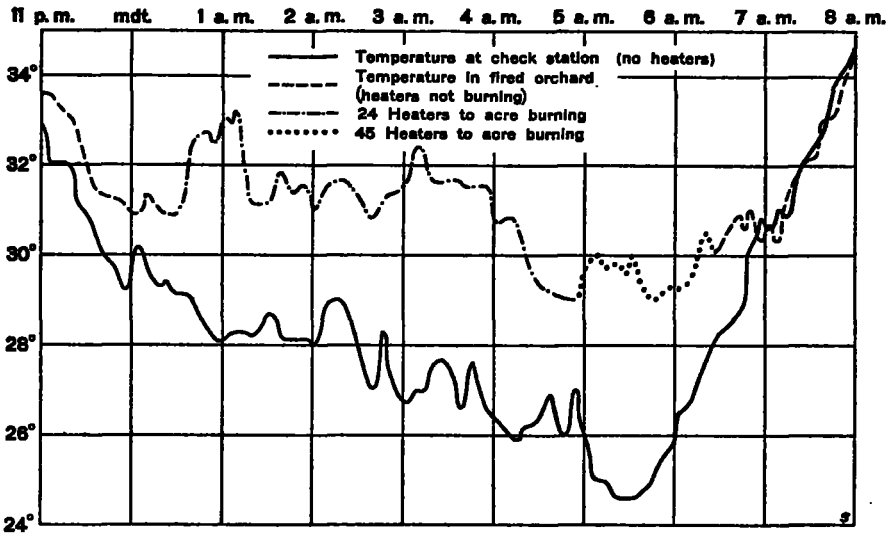

FIG. 13.—Temperature record in fired orchard and at outside check station on night of April 5–6, 1921.

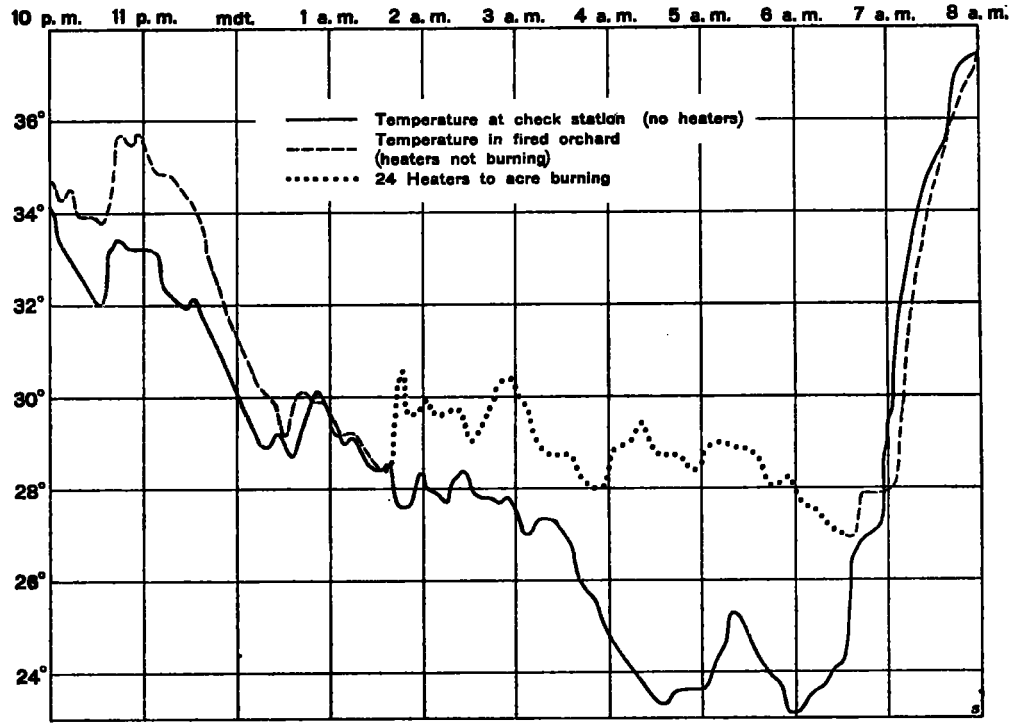

FIG. 14.—Temperature record in fired orchard and at outside check station on night of April 6-7, 1921. Temperature rose from 4 to 5° with 24 heaters to the acre burning. From 1.30 a. m., when the heaters were lighted, until 3.45 a. m. no heaters were burning within 150 feet of the station on the east and within 250 feet on the west. No heaters were lighted north of the station and none within 300 feet of the station on the south. At 3.45 a. m. a few scattering heaters were lighted in this area.

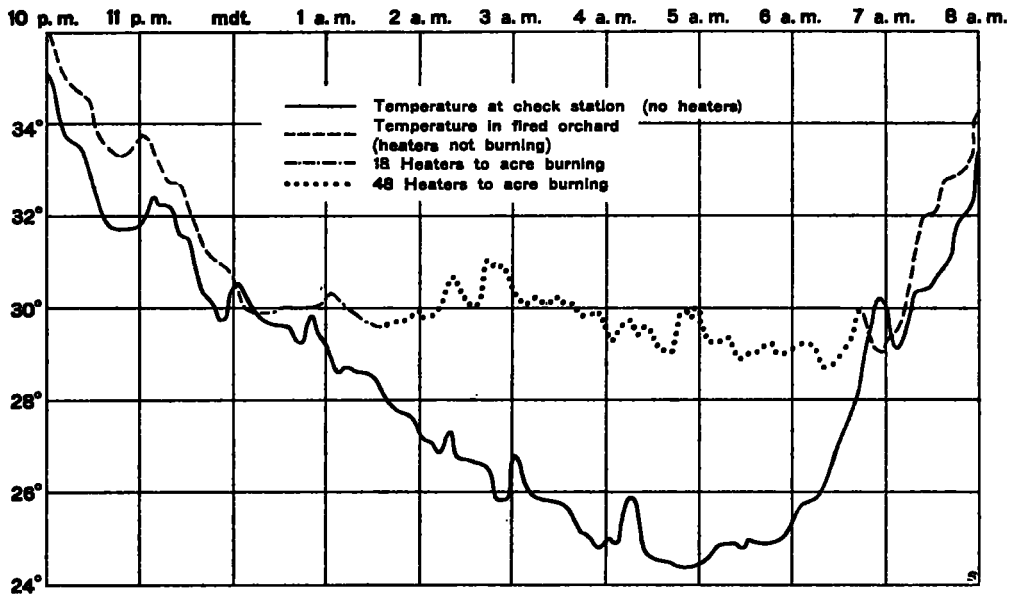

FIG. 15.—Temperature record in fired orchard and at outside check station on night of April 13-14, 1921. Temperature rose from 4 to 5° with 48 heaters to the acre burning.

located in an adjoining orchard, which contained no heaters. The effects of the firing of the heaters on different nights is shown in the diagrams.

Figure 12—Damage to fruit buds and blossoms.—Evening dew point 32°. Anjou pears in full bloom; Bartlett pears about two-thirds in full bloom; Clairgeau pears about three-fourths in full bloom; Bosc pears buds just beginning to separate in the cluster; Winter Nelis pear buds about four days before opening. Bartlett damage 50 per cent. Anjou 82 per cent. Clairgeau 60 per cent. Bosc 4 per cent, Winter Nelis 2 per cent, and Comice no damage. Trees and blossoms were covered with water and wet snow in early part of the night, and were encased in ice during latter part.

Figure 13—Damage to pear blossoms.—Evening dew point 29°. See Figure 14 for description of stage of development of pear buds and blossoms. Check station (unprotected): Winter Nelis buds show no additional damage due to this night's frost. Fired orchard: Bartlett, Clairgeau blossoms had shed most of their petals at this time. Check station (unprotected): Winter Nelis show 59 per cent injury. Anjou show 55 per cent injury. Howell show 72 per cent injury.[1] Fired orchard; Bartlett, Anjou, Clairgeau, Bosc, Winter Nelis and Comice pear blossoms show no additional damage.

EFFECT OF FROST DAMAGE ON FINAL CROPS OF FRUIT AT CHECK STATION.

Howell.—About 1 per cent of a normal crop remained on the trees at picking time.

Anjou.—About 3 per cent of a normal crop harvested.

Winter Nelis.—About 10 per cent of a normal crop harvested.

FINAL CROPS AT FIRED ORCHARD.

The damage to the crop in the fired orchard was caused almost entirely on one cold night, April 3–4. On succeeding frosty nights during the season the temperature was maintained well above the danger point through the use of orchard heaters. The percentages of full crops (estimated) for each variety in this orchard are given below. The light crop of Comice pears was not due entirely to frost damage, but at least the greater part of the reduction of the crop of other varieties of pears was probably due to frost.

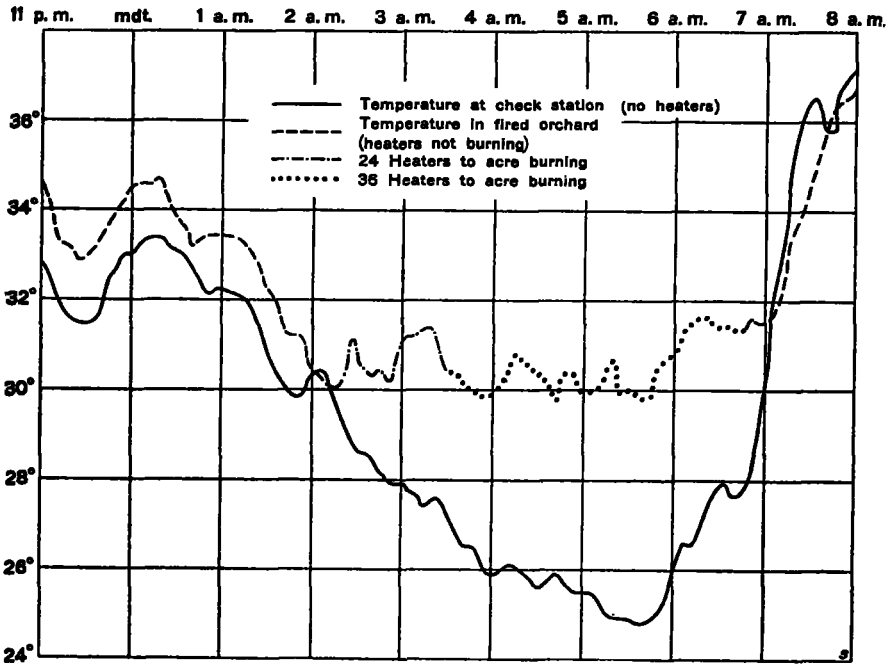

FIG. 16.—Temperature record in fired orchard and at outside check station on night of April 14–15, 1921.

Howell.—Seventy per cent of a normal crop harvested.

Anjou.—Fifty-five per cent of a normal crop was harvested. About 1 per cent of this fruit was frost marked, but not seriously. Ninety-five per cent of the fruit was on the outside of the tree, due to the fact that late bloom is found there.

Winter Nelis.—Ninety-five per cent of a full crop harvested.

Bartlett.—Eighty-five per cent of a full crop harvested, mostly on the outside of the trees. About 1 per cent were slightly frost marked.

Clairgeau, Bosc, Winter Nelis and Comice blossoms show no additional damage.

Figure 14—Damage to pear blossoms.—Evening dew point 27°. Anjou pears past full bloom; Bartlett pears in full bloom; Clairgeau pears slightly past full bloom; Bosc pear buds showing pink; Winter Nelis pear buds about two days before opening. Check station (unprotected): Howell blossoms show 86 per cent damage, including damage done on previous cold nights of season. Winter Nelis show 6 per cent damage. Fired orchard: Bartlett, Anjou, Clairgeau, Bosc, Winter Nelis and Comice pear blossoms show no additional damage.

Figure 15—Damage to buds and blossoms.—Evening dew point 33°. There was considerable cloudiness during the forenoon of the 14th, beginning before sunrise, causing frozen fruit and blossoms to thaw slowly. Practically no damage could be noted on the 14th due to this frost. Damage done on this night is included with that shown in the frost on the following night. (See fig. 16.)

Figure 16—Damage to pear buds and blossoms.—Evening dew point 33°. Winter Nelis, Bosc and Comice pears in full bloom. Howell, Bartlett, Anjou and

[1] These percentages are of blossoms remaining on the trees. Blossoms injured in previous frosts have all dropped to the ground. See percentage of full crop at end of season.

Clairgeau.—Ninety per cent of a full crop harvested, mostly on the outside of the trees. About 1 per cent slightly frost marked.

Bosc.—Seventy per cent of a full crop harvested.

Comice.—Five per cent of a full crop harvested. This variety has always been a light bearer in this orchard. The light crop was probably not due to frost injury.

DAMAGE AT SECOND LOCATION.

During the 1921 frost season a temperature station was maintained in a cold spot about 5 miles distant from the locations of the stations shown in Figures 12 to 16. The records from this station, together with estimates of the amount of damage caused on each cold night, are shown in Figures 18 to 21. This orchard was not equipped with orchard heaters.

Figure 18—Damage to fruit buds and blossoms.—Evening dew point 32°. Anjou pears in full bloom; Bartlett pears about two-thirds in full bloom; Clapp Favorite pears in full bloom; Bosc pear buds just beginning to separate in the cluster; Winter Nelis pear buds about four days before opening. Bartlett damaged 90 per cent, Anjou 78 per cent, Bosc 20 per cent, Winter Nelis 31 per cent, and Clapp Favorite 80 per cent. Compare with damage to same varieties in Figure 14. Trees and blossoms were covered with water and wet snow in early part of the night, and were encased in ice during the latter part. All trees about 15 years old.

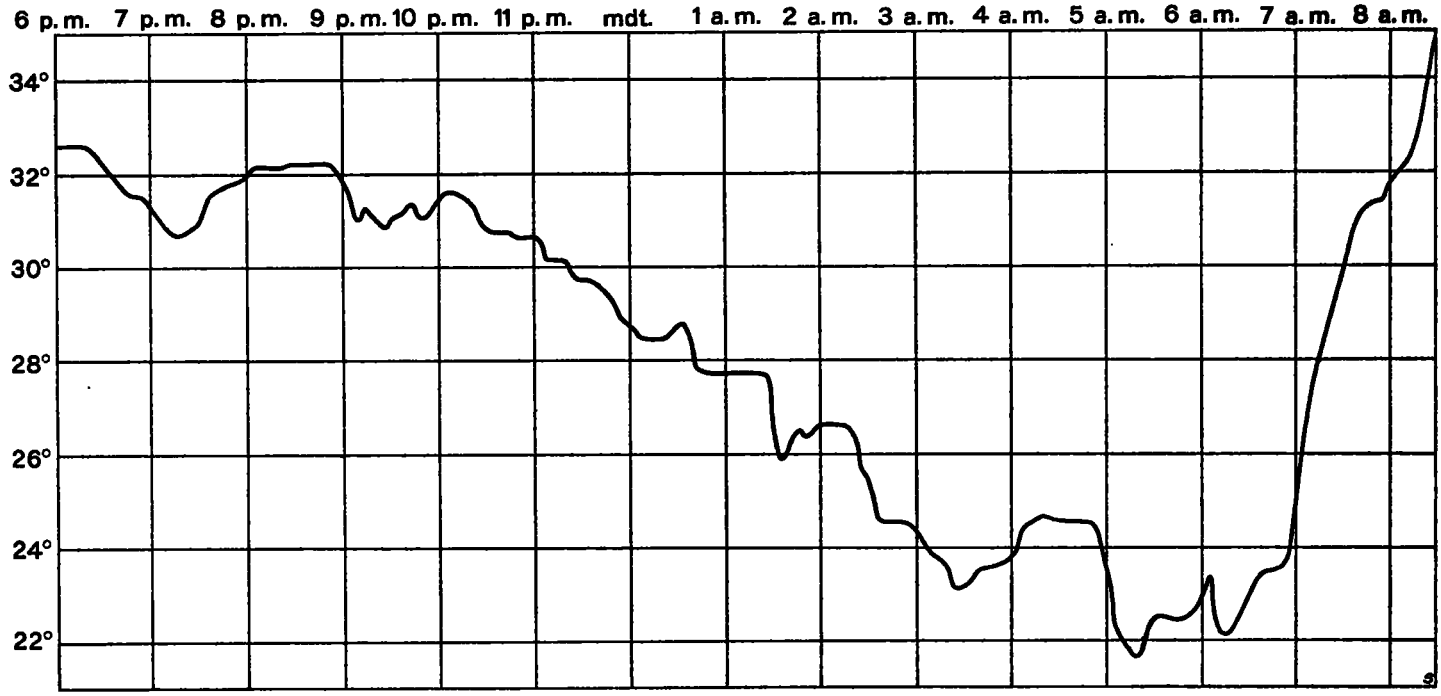

FIG. 18.—Temperature record in an orchard not equipped with orchard heaters, April 3-4, 1921.

Figure 19—Damage to buds and blossoms.—Evening dew point 29°. Bartlett show 92 per cent damage, Anjou 88 per cent, Bosc 98 per cent, Winter Nelis 44 per cent, and Clapp Favorite 90 per cent. These percentages include damage done on previous night. Damage due to night of April 5–6: Bartlett 2 per cent, Anjou 10 per cent, Bosc 78 per cent, Winter Nelis 13 per cent, and Clapp Favorite 10 per cent. Note that about 95 per cent of the Bosc and Winter Nelis blossoms were not open at this time.

Figure 20—Damage to buds and blossoms.—Evening dew point 27°. No additional damage was found following this frost. Practically all the more advanced blossoms had been badly damaged or killed on the previous night, leaving only the latest bloom showing clear. This late bloom, as a rule, was not damaged by the frost on the night of the 6th–7th.

Figure 21—Damage to blossoms and fruit.—Evening dew point 33°. Winter Nelis, Bosc, and Comice pears in full bloom. Howell, Bartlett, Anjou, and Clapp Favorite blossoms had shed most of their petals at this time. Winter Nelis show 42 per cent injury, Anjou 60 per cent, Bosc 99 per cent, Bartlett 81 per cent, and Clapp Favorite 83 per cent injury. In the case of all these varieties except Bosc, the fruit had formed at this time, and all blossoms damaged in previous frosts had dropped from the trees. These percentage estimates cover fruit that had escaped injury in former frosts. In some cases there was practically no fruit left on the trees to be damaged by this latest frost.

Probably the most interesting feature in connection with these records is the killing of practically all the blossoms on Bosc trees before they had opened, by temperatures of 22° F. and 23° F. Winter Nelis blossoms also were killed, to a lesser extent, in these two frosts.

EFFECT OF FROST DAMAGE ON FINAL CROP.

Anjou.—Three per cent of a normal crop harvested.

Winter Nelis.—Five per cent of a normal crop harvested.

Bartlett.—Fifty per cent of a normal crop harvested. practically all badly frost marked and misshapen.

Bosc.—Two per cent of a normal crop harvested.

Clapp favorite.—Fifty-five per cent of a normal crop harvested. Most of crop in upper half of tree. Nearly all seedless and misshapen. Seedless pears still falling to the ground at picking time. Ground covered with nearly mature fruit.

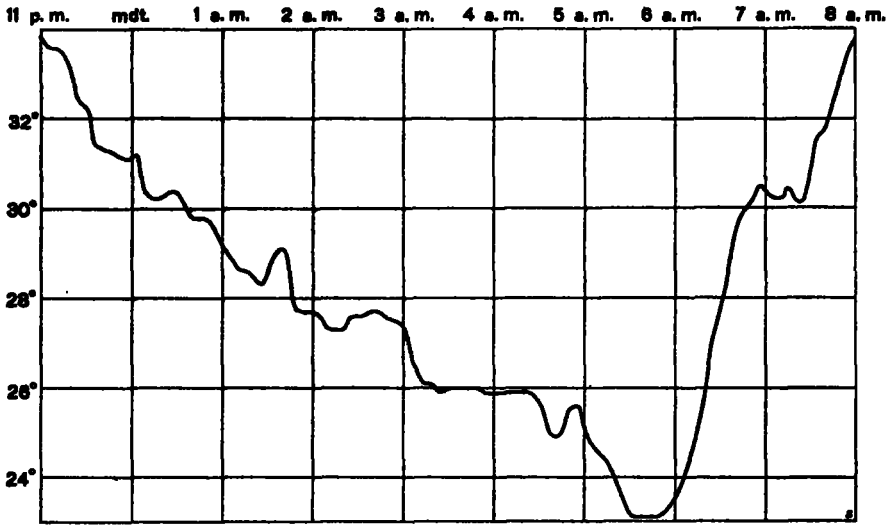

FIG. 19.—Temperature record in an orchard not equipped with orchard heaters, April 5-6, 1921.

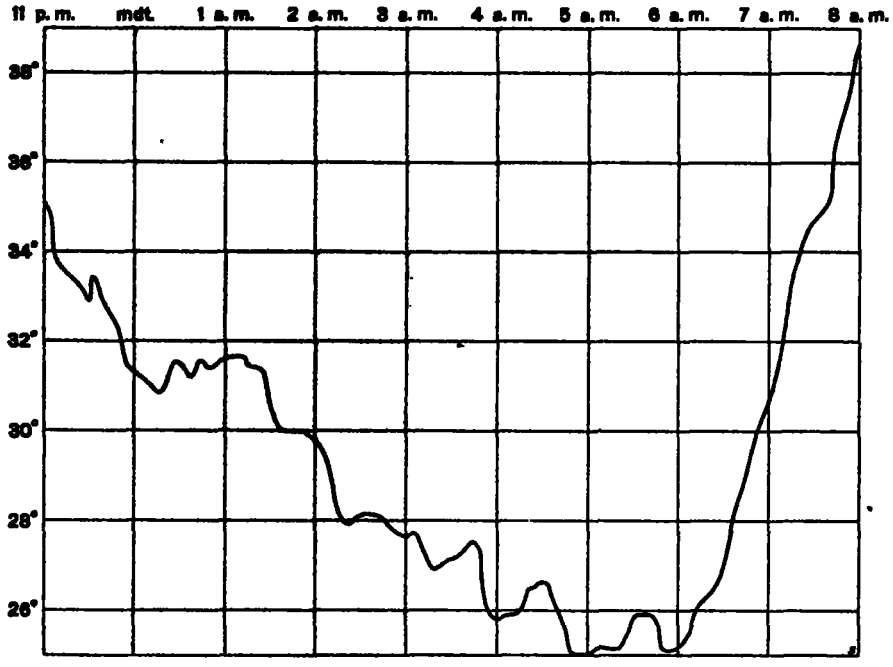

FIG. 20.—Temperature record in an orchard not equipped with orchard heaters, April 6-7, 1921.

A particularly close study was made of a Clapp Favorite tree at station 2, following the first cold night, which caused 80 per cent of the blossoms to show deep discoloration. This tree was about 15 years old and from outward appearances in a vigorous condition. It carried a heavy bloom.

Following the last heavy frost on the night of April 14–15, a careful count showed about 83 per cent of the fruits, which were about the size of peas at that time, were badly discolored. If all the fruit on the tree at this time had matured there would have been more than the tree could carry at the end of the season. The injured fruits were so badly discolored that it was possible to tell by inspection, without cutting the fruits, which were injured. At this time it was difficult to find an undamaged fruit on the tree.

On May 6 this tree was again examined to see whether the discolored fruits had fallen from the trees. There was some fruit on the ground on this date, but very little in comparison to the total amount of damaged fruit on the tree. None of the fruit, however, injured or uninjured, seemed to be making much growth.

On August 9 this tree still carried 55 per cent of a full crop. The ground underneath the tree was covered with large, seedless, misshapen fruits, and the drop was still continuing. The fruit in the lower half of the tree was practically 100 per cent frost marked and seedless. (See fig. 38.) The crop was considerably heavier near the top.

On September 2 the fruit on this tree was picked and measured in field boxes and graded entirely on the basis of shape. There were four boxes of badly misshapen and seedless fruit and one box of fruit of normal shape on the tree, and one and one-fourth boxes of mature fruit was on the ground under the tree. A great many of the pears in the box of normal shaped fruit were frost marked.

These observations are especially interesting in showing that even though this variety of pear may be so severely injured by frost that the seeds are killed, a considerable portion of the crop may remain on the trees until maturity, although the fruit is likely to grade very low. Another interesting point is the fact that about one-sixth of a normal crop of fairly good fruit was matured, although temperatures of 21.5° F. and 23° F. were recorded during the period when the tree was in full bloom.

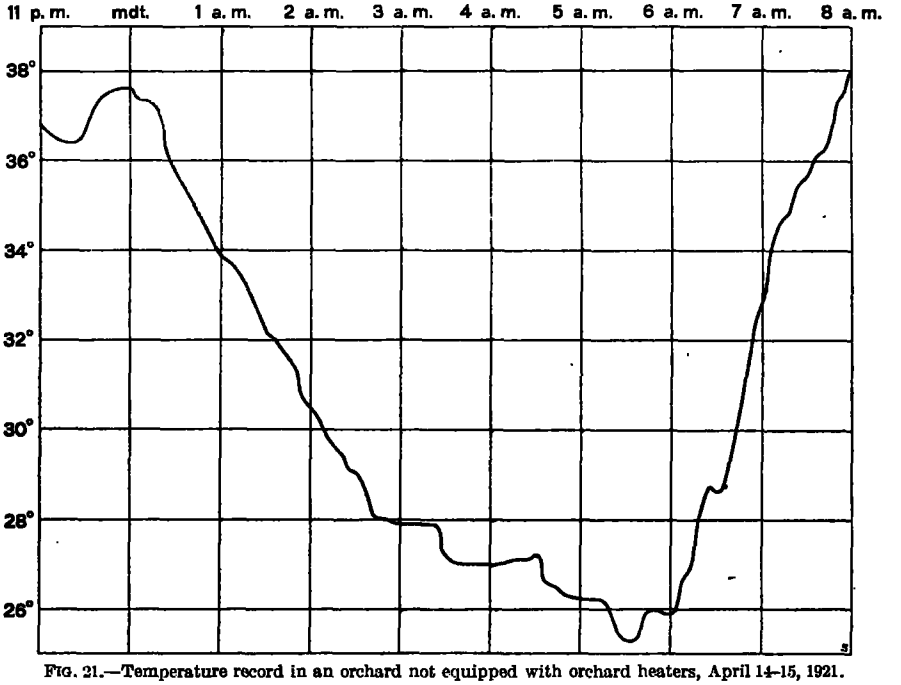

FIG. 21.—Temperature record in an orchard not equipped with orchard heaters, April 14-15, 1921.

WILL FRUIT WITH BLACKENED CENTERS MATURE?

This is a question regarding which there has always been great difference of opinion among practical growers of fruit. Following a heavy frost which has discolored a large percentage of the fruits on the trees, some growers feel sure the crop is lost. Others take exactly the opposite view, and maintain that all the injured fruits will mature and make good first-grade fruit at the end of the season.

In order to gain some information on this question, several clusters of different varieties of pears were tagged soon after the fruit had formed in the spring of 1921 and a close watch was kept of them during the remainder of the season. In all the clusters marked, it was possible to pick out the fruits with discolored centers without cutting. All injured fruits of this kind showed darkened calyx ends.

Notes on these observations are given below.

Bartlett fruits.—Irrigated trees, 9 years old. Soil, Olympic adobe. Orchard care excellent.

April 12, 1921: Four clusters of five Bartlett pears each tagged; petals all have fallen. Every fruit shows injury without cutting. The best appearing fruit in a similar cluster, when cut, showed deep discoloration. All fruits are growing well, and from outward appearances are vigorous and healthy.

April 20, 1921: All clusters except one are showing a sickly yellow and appear about ready to drop.

May 9, 1921: Only three pears left, all in one terminal cluster. Two of these are badly frost-marked (ring-necked).

June 9, 1921: All pears in tagged clusters have fallen to the ground.

August 9, 1921: About 14 pears remain on entire tree, mostly near the top.

FIG. 35.—Mature Bartlett pears, showing woody russet markings on the frost-injured fruit.

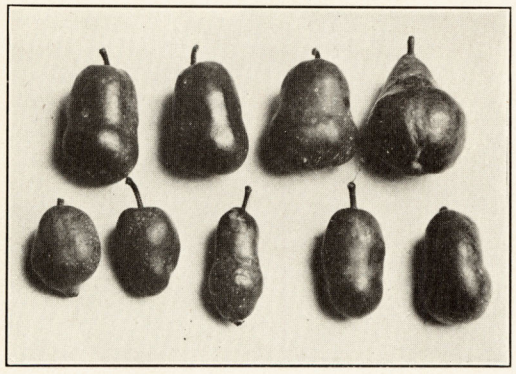

FIG. 36.—Odd shapes assumed by Bartlett pears in which the seeds have been killed by frost. The pear in the upper right-hand corner is of normal shape and size.

FIG. 37.—Clapp Favorite pears in which the seeds have been killed by frost. The three pears in upper right-hand corner are of normal size and shape.

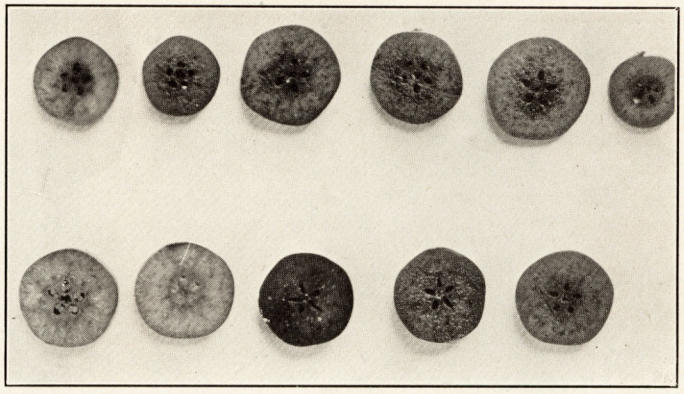

FIG. 38.—Cross sections of young pears, showing effect of frost. Two fruits in lower left-hand corner are normal; others are seedless and discolored.

FIG. 39.—Howell pears from an orchard protected with heaters, after the heavy frosts of 1921. A heavy crop was set and the fruits grew rapidly. Compare with a topical branch of Howell pears from tree in unprotected orchard, shown in Figure 40.

FIG. 40.—Typical branch from Howell pear tree in unprotected orchard near that from which the branch shown in Figure 39 was obtained. All blossoms were stunted and yellow, and fell rapidly. A large proportion of the blossoms fell from the branch while it was being brought in to be photographed. A condition of this kind is very often attributed by the grower to "lack of pollination."

FIG. 41.—Average size of crop per tree of Bosc pears harvested in orchard protected with lard-pail orchard heaters during the severe frost season of 1921.

FIG. 42.—Excellent crop of Bosc pears harvested in 1922 in orchard which was protected from frost damage with lard-pail orchard heaters. Same orchard as in Figure 41.

FIG. 43.—Average size of Bosc pear crop per tree in 1922 in orchard protected from frost damage with lard-pail orchard heaters. Compare with Figure 41, which shows same orchard in previous year. Some irrigation.

FIG. 44.—Average size of crop per tree of Anjou pears in orchard protected from frost damage with lard-pail orchard heaters, 1921 season. Compare with Figure 46.

FIG. 45.—Crop of Anjou pears harvested from one of the larger trees in orchard which was protected from frost damage with lard-pail orchard heaters during the 1921 season. Compare with Figure 46.

FIG. 46.—Average yield of Anjou pears per tree in 1921 in orchard directly across the road from that shown in Figures 44 and 45. This orchard was not protected from the unusually severe spring frosts, and yielded only about three-fourths box of fruit per tree. Compare size of crop with that shown in Figures 44 and 45.

Bartlett blossoms.—(Same block of trees as above.)

April 12, 1921: Two terminal clusters, containing six blossoms each, in full bloom, were tagged for observation on this date. In each cluster four blossoms show discoloration and two do not appear to be discolored.

May 9, 1921: All pears have dropped from one cluster. In second cluster two apparently vigorous pears remain. Second bloom on tree is now in full bloom. In the cluster from which all the pears have dropped, one tiny new bud has appeared since the fruit has dropped.

June 9, 1921: One pear, badly frost-marked, remains.

August 9, 1921: One pear, badly frost-marked, remains.

Anjou blossoms.—Irrigated trees, 9 years old. Soil, Olympic adobe. Orchard care excellent.

April 12, 1921—Cluster No. 1: Seven blossoms in cluster, all showing discoloration.

Cluster No. 2: Eight in cluster; six show discoloration, and two appear to be in good condition.

Clusters No. 3: Two clusters, with seven blossoms each. One blossom in each cluster appears to be in good condition; others show discoloration.

April 20, 1921—Cluster No. 1: Two fruits seem to be making good growth and appear to be healthy and vigorous.

Cluster No. 2: Three fruits are red and appear to be healthy and vigorous. All fruits in this cluster now show black at calyx ends.

Cluster No. 3: Several fruits are apparently healthy, and are making rapid growth.

May 9, 1921—Cluster No. 1: Only one pear remains and it does not appear to be healthy.

Cluster No. 2: One pear still hanging; remainder have been shed.

Cluster No. 3: Four pears remain. One appears to be healthy and vigorous. The other three are stunted, but are still growing.

June 9, 1921—Cluster No. 1: All fruits have been shed.

Cluster No. 2: All fruits have been shed.

Clusters No. 3: One pear remains.

August 9, 1921: All clusters marked are now bare of fruit. The tree on which they are carried has about one-half box of fruit, most of which is badly frost-marked.

Anjou Fruits.—Irrigated trees, 9 years old. Soil Olympic adobe. Orchard care excellent.

April 20, 1921: Four clusters, containing five fruits each, tagged for observation. Every fruit shows discoloration, but all are making vigorous growth.

May 9, 1921: No fruits are now making normal growth. Dropping off rapidly. Two clusters are bare of fruit. All fruits are seedless and mis-shapen.

June 9, 1921: All fruits have been shed.

Bosc blossoms.—Irrigated trees, 9 years old. Soil Olympic adobe. Orchard care excellent.

In many orchards throughout the valley, more than 90 per cent of the Bosc blossoms were killed by the low temperatures on the nights of April 3–4 and 5–6 (see figs. 12 and 18), while the buds were still tightly closed. These trees came into bloom about April 12. Unless examined closely, the trees appeared to be in perfect condition. There was a great profusion of bloom. However, when the blossoms were examined, from 90 to 100 per cent of the pistils, stamens, and anthers were black and leathery. The ovules did not appear to be injured.

April 12, 1921: Five clusters of Bosc blossoms, every blossom in which has blackened and dried pistils, stamens and anthers, were tagged on this date.

May 9, 1921: Every blossom in every cluster marked has dropped.

NOTES ON SEASONAL DATA.

In studying the effects of the frosts of 1921, it was noted that not only was the crop heavier in the tops of the trees, on account of the difference between the temperature of the air near the ground and that at the elevation of the tops of the trees on frosty nights, but where the damage was not total, the fruit which matured was from terminal clusters of blossoms, which usually bloom considerably later than blossoms in the interior of the tree. This difference between the time of full bloom of blossoms in the interior of the tree and those in terminal clusters is especially marked in the Bartlett and Clairgeau.

In the few orchards which were carefully protected with orchard heaters throughout the frost season the fruit was well distributed throughout the trees.

The terminal blossom clusters are found on long, weak branches, of small diameter, which will hold one or two pears each, at most. These small branches are easily swayed by the wind, and much of the fruit is scarred through limb rubbing in a normal season. Blossoms in the interior of the trees were considerably farther advanced at the time the heavier frosts occurred, and were practically all killed. Thus, the interior of the tree, where the branches were large enough to carry heavy crops. were practically bare of fruit.

The effect of the stratification of the air on frosty nights on the final crop of pears is shown in Figures 30 and 31. Several acres of Comice pears carried a heavy crop of fruit near their tops, but very little fruit in the lower half of the trees. In the tree shown in Figure 30 not one pear was found below 8 feet above the ground. Between 8 feet and 12 feet 39 pears were picked. From 12 feet to 16 feet 112 pears were picked. This condition was quite general throughout the valley, where there was no firing during the 1921 season.

During the 1922 frost season the orchard was protected from frost damage with orchard heaters. At picking time the same tree was examined and the same data as to production gathered. Figure 31 shows the results graphically.

It is well known that blossoms on a young tree are more susceptible to injury by frost than those on an older tree, up to certain limits. To illustrate this fact, two Howell pear trees, side by side in an orchard were selected, one 4 years and the other 16 years old. A count of damaged blossoms on April 12, 1921 showed 4 per cent damage in the older tree and 85 per cent damage in the younger tree. At picking time in the fall the larger tree bore 80 per cent of a full crop, while the crop on the small tree was only 5 per cent of the amount of fruit it should have carried.

OBSERVATIONS DURING THE 1922 SEASON.

The spring of 1922 was very cold and backward and all varieties of pears bloomed from three to four weeks later than usual. Data on the effect of low temperatures in damaging blossoms and young fruit were secured at nine different locations during the season. Most of the temperature stations used in this work were located in the colder parts of the valley. On account of the lateness of the season, there was very little damage to fruit by frost during the spring. The records are of value principally in showing what low temperatures can be experienced, without materially decreasing the size of the final crop in fall. Temperature records for 1922 are shown in Figures 22 to 29.

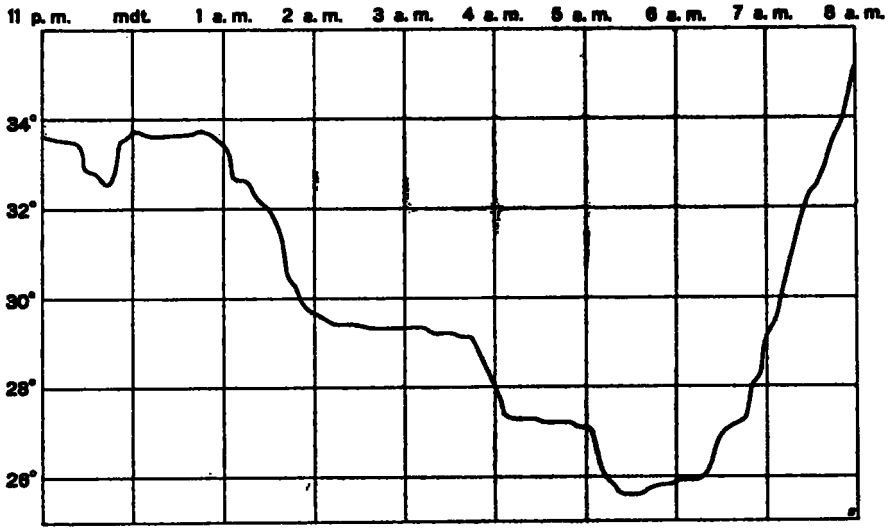

FIG. 22.—Temperature record in a cold pear orchard on the night of April 16-17, 1922, when no heatres were lighted, and temperature records at two stations about one-half mile apart which were almost identical.

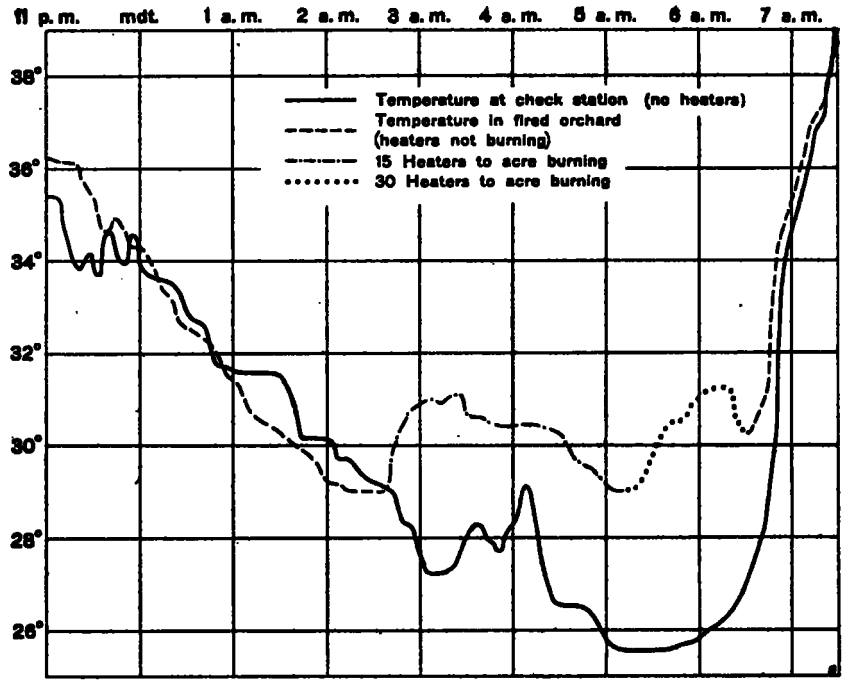

FIG. 23.—Temperature record in fired orchard and in an unprotected orchard, stations one-half mile apart, night of April 27-28, 1923.

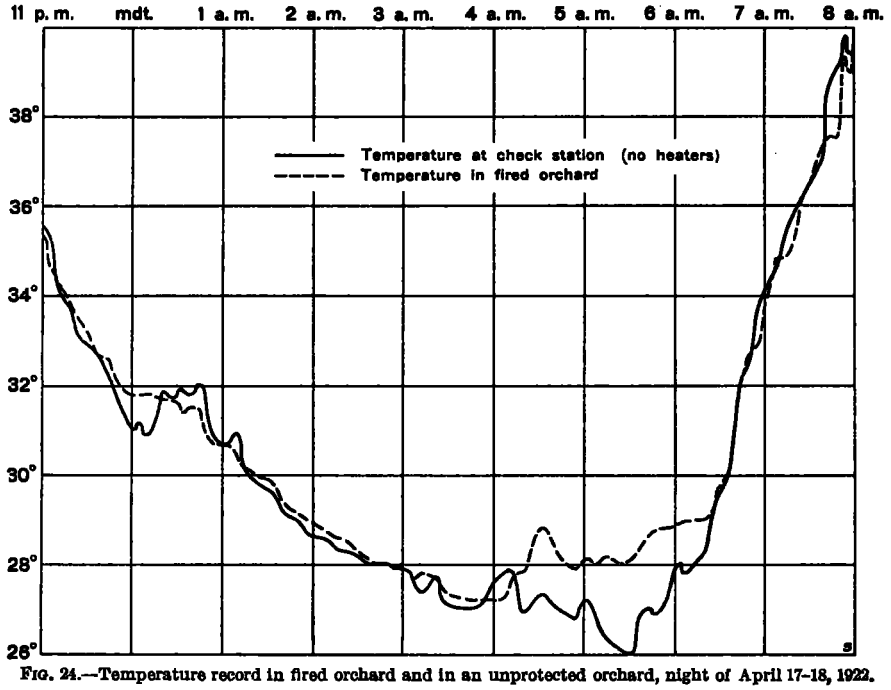

FIG. 24.—Temperature record in fired orchard and in an unprotected orchard, night of April 17–18, 1922.

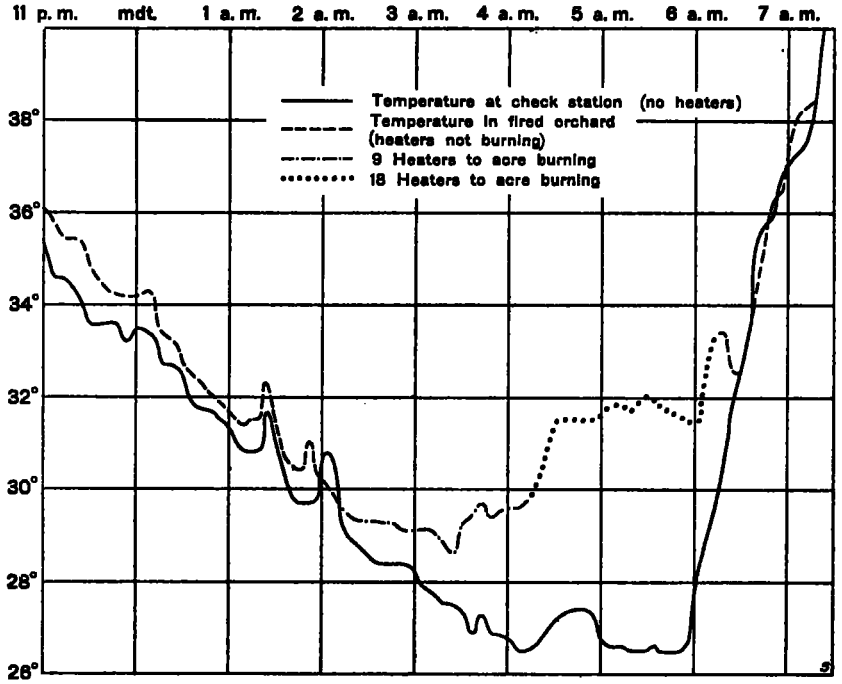

FIG. 25.—Temperature record in fired orchard and in an unprotected orchard, night of April 27–28, 1922. Temperature rose 5½° F. with use of 18 high-stack oil heaters to the acre.

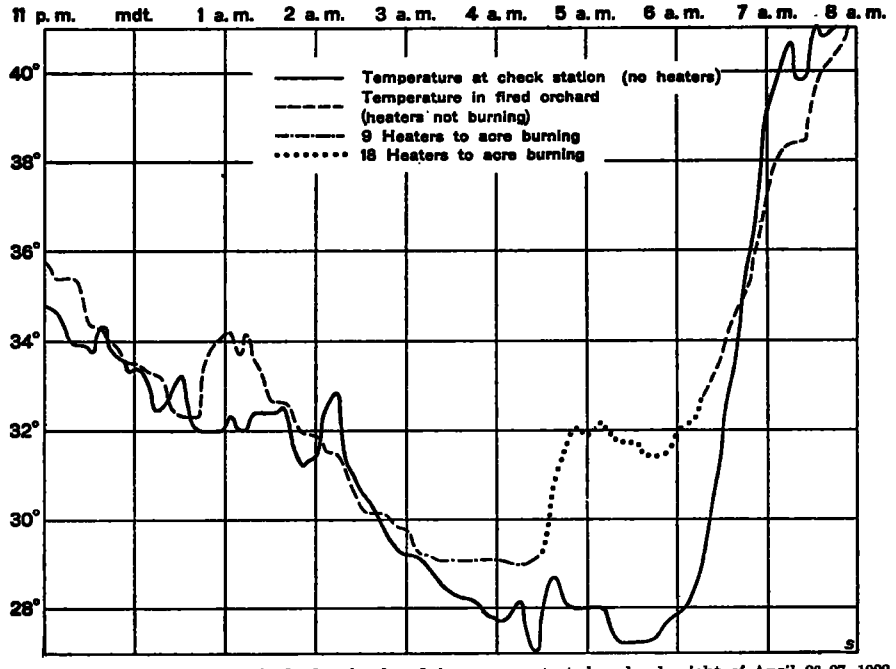

FIG. 26.—Temperature record in fired orchard and in an unprotected orchard, night of April 26-27, 1922. Temperature rose about 4° with 18 high-stack oil orchard heaters to the acre.

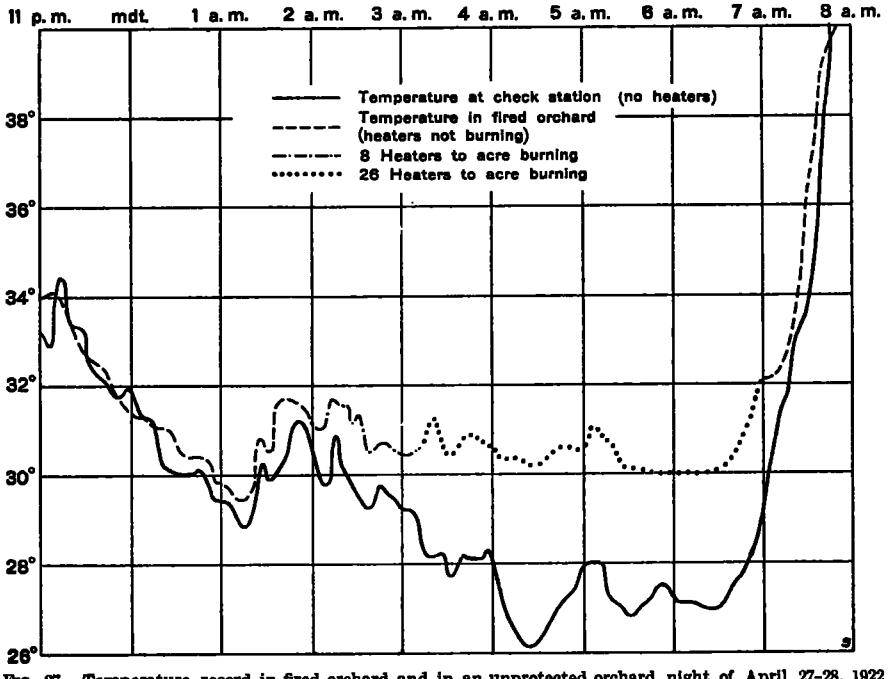

FIG. 27.—Temperature record in fired orchard and in an unprotected orchard, night of April 27-28, 1922. Temperature rose from 3° to 4° with 26 high-stack oil orchard heaters to the acre.

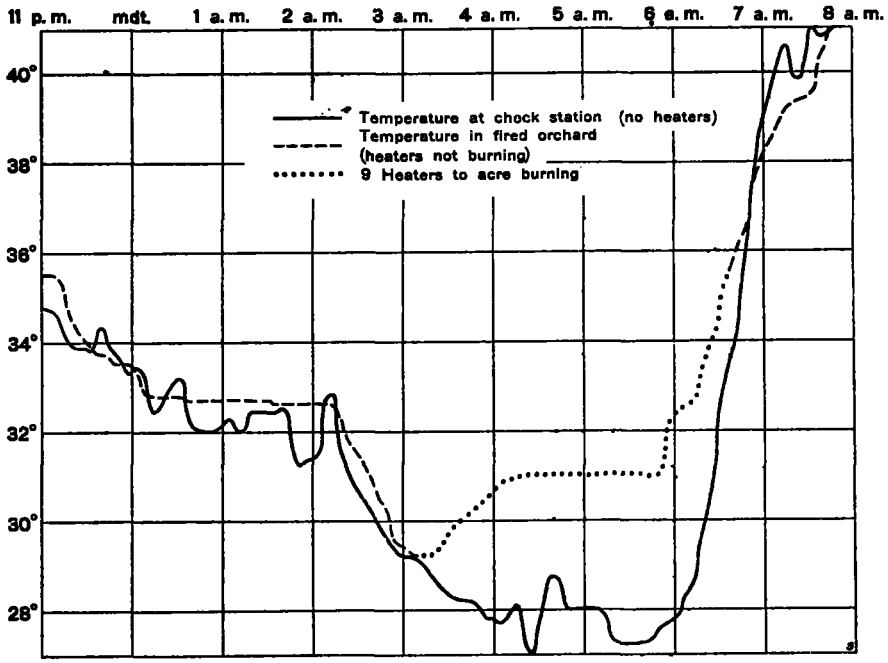

FIG. 28.—Temperature record in fired orchard and in an unprotected orchard, night of April 26-27, 1922. Temperature rose about 4° with nine 5-quart lard-pail oil heaters to the acre.

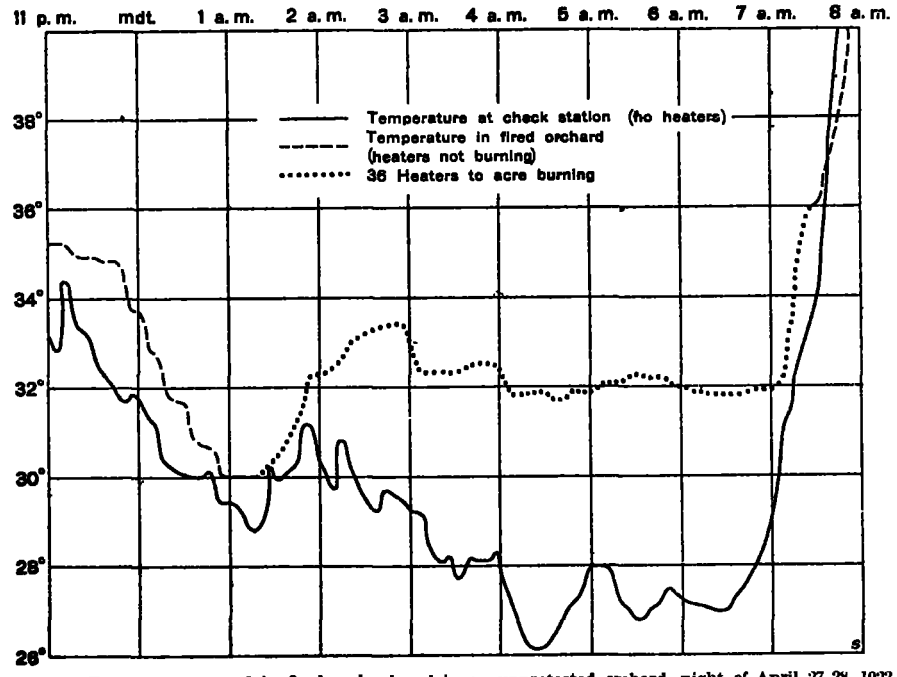

FIG. 29.—Temperature record in fired orchard and in an unprotected orchard, night of April 27-28, 1922. Temperature rose 5 or 6° with 36 5-quart lard-pail oil heaters to the acre.

The frost of April 16–17 did so little damage that it was practically negligible; it is interesting only for the fact that a few buds were killed while in a very early stage. (See fig. 32.) It seems probable that this frost was responsible for the marking of a large percentage of the Bartlett crop in the vicinity of station 6.

The next frost, on the morning of the 27th–28th, killed the greater portion of the Bosc blossoms where the temperature remained at 25.5° for one hour. The damage caused by this frost, which was the heaviest of the season, is shown in the temperature diagrams for that date. (Figs. 23, 25, 27, and 29.)

Figure 22—Damage to buds.—Evening dew point 33°. Photograph (fig. 32) shows stage of development of pear buds: Anjou buds damaged 18 per cent; Bartlett 11 per cent; Bosc 2 per cent; Comice 4 per cent.

Figure 23—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom; Bartlett in full bloom; Bosc and Comice opening. Check station (unprotected): Anjou blossoms show 24 per cent additional injury, or total percentage of blossoms injured by all frosts to date, 50 per cent. Bartlett blossoms show 26 per cent additional, or total percentage 41; Bosc (young tree) shows practically every blossom killed. Old Bosc tree in adjoining orchard, on higher ground, and undoubtedly somewhat warmer location, shows 81 per cent damage. About 50 per cent of the king buds on old Yellow Newton apple trees, just beginning to show pink, were killed on this date. Fired area: Anjou, Bartlett, Bosc, and Comice blossoms show no additional damage. Bartlett blossoms in same orchard, but not protected, show 52 per cent damage.

Figure 24—Damage to fruit buds.—No damage could be found in the valley, due to this frost.

Figure 25—Damage to pear buds and blossoms.—Evening dew point 29°. Bartlett pears in full bloom; Howell pears slightly past full bloom. Anjou pears past full bloom; Winter Nelis not yet open. Check station (unprotected): Bartlett blossoms show 21 per cent damage; Howell blossoms show 9 per cent damage. Fired orchard: Anjou (large trees) in interior of orchard, near temperature station, show no damage. Small Anjou tree, 6 years old, in interior of orchard, shows 20 per cent damage. Anjou trees, 9 years old, on windward border row, 68 per cent damage. Bartlett and Winter Nelis blossoms show no additional damage.

Figure 26—Damage to pear blossoms.—Evening dew point 32°.

Anjou pears slightly past full bloom; Bartlett pears in full bloom; Bosc and Comice blossoms not yet open. Fired orchard: No damage to any variety.

Figure 27—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom: Bartlett in full bloom; Bosc and Comice opening. Fired orchard: No damage to any variety of pears.

Figure 28—Damage to pear blossoms.—Evening dew point 32°. Anjou pears slightly past full bloom; Bartlett pears in full bloom; Bosc and Comice blossoms not yet open. Check station (unprotected): Bartlett blossoms show 7 per cent injury. Fired orchard: No damage to any variety of pear blossoms.

Figure 29—Damage to pear blossoms.—Evening dew point 29°. Anjou pears past full bloom; Bartlett in full bloom; Bosc and Comice opening. (Check station unprotected): Bartlett blossoms show 23 per cent injury. Fired orchard: No damage to any variety of pear blossoms.

EFFECT OF FROST DAMAGE ON FINAL CROPS; 1922 SEASON.

(Percentages of full crops harvested.)

Station 1.—Irrigated trees, 25 years old; soil clay adobe; orchard care excellent.

Fired orchard: Anjou,[2] 80 per cent; Bartlett, 85 per cent; Bosc, 85 per cent; Howell, 100 per cent; Winter Nelis, 100 per cent; Clairgeau, 100 per cent.

Check station: Bartlett, 95 per cent.

Station 2.—Fired orchard: Irrigated trees, 18 years old; soil clay adobe; orchard care excellent. Bartlett, 100 per cent; Anjou,[2] 95 per cent.

Station 3.—Fired orchard:[3]— Irrigated trees, 16 years old; soil clay loam; orchard care excellent. Bosc, 100 per cent; Anjou,[2] 80 per cent; Bartlett (in same orchard, but only partly protected by drift of heat from orchard heaters in adjoining blocks) 95 per cent full crop, 30 per cent badly frost marked.

Check station: Irrigated trees, 14 years old; soil clay loam; orchard care excellent. Bosc, 1 per cent; Anjou,[3] 5 per cent; Bartlett, 40 per cent full crop, 20 per cent badly frost marked.

Station 4.—Fired orchard: Irrigated trees, 10 years old; soil Olympic adobe; orchard care excellent. Anjou,[2] 50 per cent; Bartlett, 100 per cent; Winter Nelis, 95 per cent.

Check station: Irrigated trees, 14 years old; soil Olympic adobe; orchard care excellent. Bartlett, 100 per cent; Howell, 100 per cent.

Station 5.—Fired orchard:[4] Natural subirrigation; trees 15 years old; soil sandy loam; orchard care excellent. Anjou,[2] 20 per cent; Bartlett, 98 per cent full crop, 25 per cent frost marked.

Station 6.— Fired orchard: Irrigated trees, 16 years old; soil sandy loam; orchard care excellent. Anjou,[2] 20 per cent; Bartlett, 100 per cent of full crop, 2 per cent frost marked.

On the night of May 25–26, 1922, a heavy frost occurred in some of the colder spots in the valley. In a few orchards Bartlett pears, of the size shown in Figure 34, were frozen almost through. A few were found with even the seeds frozen, although in most cases the frozen tissue stopped short of the seed cavities. The fruits assumed a dark green, water-soaked appearance, and minute blisters appeared on the skin. A very few fruits were found with cracks in the skin.

Ten clusters of the Bartlett, showing the greatest evidence of freezing, were tagged, and a close watch was kept of them during the remainder of the season. Fully as much fruit matured in these marked clusters as on trees in an adjoining orchard which was protected with orchard heaters, and there was no marked difference in the percentage of high-grade fruit.

It is probable, however, that if the low temperature had continued for a slightly longer time, so that the seeds had been frozen, both the size and quality of the final crop would have been reduced.

CONCLUSION.

The studies conducted in the Rogue River Valley indicate that all the commercial varieties of pears will show slight injury following a temperature of 25.5° F. for

[2] Weather during period of Anjou full bloom was cold and rainy, and very unfavorable for pollination. Small crop due in most cases to this factor, rather than frost damage.
[3] Crop badly injured by frost.
[4] Heaters not fired on one cold night and considerable damage occurred.

about one hour while the buds are showing pink. This also applies to Yellow Newtown apples. The number of buds injured is so slight that the final crop is not affected. in the case of pears, at least. Bosc pears appear to be considerably more susceptible to injury in this stage than other varieties. Winter Nelis pears seem to be more hardy in this stage than any other variety of pears grown commercially in the valley. Winter Nelis also appears to be more hardy while in full bloom than other varieties.

It should be borne in mind that a discoloration of the blossoms or fruit was used entirely as a basis for estimating damage by the different frosts. It is recognized that this is not a perfect method of calculating the amount of damage, as the vital organs of the flower may be injured so that pollination is prevented, without any marked discoloration of the ovules. A sickly yellow color of the pistil was often found following a frost, in flowers which otherwise appeared to be in perfect condition. Whether such a flower was seriously damaged or not, would depend on whether it had been pollinized prior to the frost.

It should be remembered also that all temperatures mentioned in this paper are readings of sheltered thermometers. Unsheltered thermometers, that is, thermometers freely exposed to the sky, would have shown temperatures from one to three degrees lower. Just what the real temperature of the blossoms might be is not known but probably differs from those given.

It was noticed during the 1922 frost season that a temperature of from 25.5° F. to 26.0° F. had been experienced in unprotected orchards, the calyx cups showed a very dry condition; there were no globules of nectar which are found ordinarily. This dry condition and lack of nectar was not found in blossoms in the orchards which had been protected with orchard heaters and the temperature had not been allowed to fall below 28° F.

Whether or not a pear blossom or young fruit will mature after it has been injured by spring frosts to such an extent that the ovules or seeds are blackened depends on the variety. Under the most favorable conditions, probably not more than a very small percentage of blossoms or fruits thus injured will mature. From close observation, covering six frost seasons, it appears that Clapp Favorite, Bartlett, Anjou and Howell pear trees, in the order named, will mature some fruit in which pollination has been prevented or the seeds killed by spring frosts. The Clapp Favorite tree, mentioned on a preceding page, matured four full field boxes of fruit which was entirely seedless as a result of frost injury.

Bartlett trees often set considerable seedless, frost-marked fruit, but usually most of it drops to the ground before the end of the season. The writers often have seen seedless Bartlett fruits remain on the trees until two or three weeks before picking time, and then all fall to the ground within a few days.

In some sections the Bartlett seems to require cross-pollination, and where pollen from suitable varieties is lacking, a fair sized crop of seedless fruit may be matured, even when there is no frost damage. In the Rogue River Valley, so many varieties of pears are grown commercially, in small blocks, there is no lack of pollen for cross-pollination.

Only a very few seedless Anjou pears are likely to be found on the trees at any time. Anjou ability to mature such fruits is much less than in the case of the Bartlett, but an occasional seedless fruit is found.

The Howell seldom matures fruit that has been seriously injured by frost, and Winter Nelis, Comice, and Bosc, practically never.

Usually a small percentage of Yellow Newtown apples which have been severely injured by frost, will mature.

In the case of all the varieties which mature seedless, or nearly seedless fruit, due to frost injury, most of the crop is so marked and misshapen that it is unfit for the market. Pears which are slightly frost-marked are sometimes handled by the canneries, but they are not usually in demand, even for this purpose. The russet rings which form around the fruit, often grow woody toward the end of the season, making them difficult to peel and handle. Figures 35, 36, and 37, show frost-marked fruit and odd shapes assumed by fruits in which the seeds have been killed by frost. Figure 38 shows the difference in appearance between the cross-sections of injured small pears.

In a normal season, Bartlett and Clairgeau blossoms in the interior of the tree, on the older and heavier wood, open several days sooner than blossoms on the ends of the smaller and weaker branches at the outside of the tree. An early frost often kills the interior and earlier bloom, but does not injure the later terminal bloom. In such cases a fairly large crop of fruit may be harvested, but there is danger of breaking limbs off the trees, and the terminal fruit at the ends of the whiplike branches is likely to be scarred by limb rubbing.

CRITICAL TEMPERATURES.

There seems to be no questioning the fact that the generally accepted critical temperatures for pear blossoms do not apply in the Rogue River Valley. The temperature and damage records for the night of April 3–4, 1921 (Fig. 12), is interesting from this standpoint. The temperature was below 32° F. for 14 consecutive hours, and below 28° F. for five consecutive hours, with a minimum temperature of 21.6° F., yet the reduction of the final crop of Bartlett and Clairgeau pears, which were in full bloom at the time, was only from 10 to 15 per cent.

Another point that needs emphasizing is the fact that there is usually a greater difference between the critical temperatures for different varieties of the same fruit than there is between the average critical temperatures for two different kinds of fruit, generally speaking. Judging by the actual yields of fruit in the orchard, which was adequately protected on every cold night except April 3–4, during the 1921 season, there was 15 per cent more damage to Bosc buds, which were barely showing pink and were scarcely separated in the clusters, than to the Bartlett, which was over 90 per cent in full bloom. From a comparison of the final yields of fruit in the fall, there was only 15 per cent more damage to Anjou pears, practically 100 per cent in full bloom, than to Bosc in the pre-pink stage, as mentioned above.

It is impossible to name a definite critical temperature for blossoms or fruit at any stage of development, since the duration of the temperature and the preceding weather and growing conditions must be taken into consideration. Weather conditions on the day following a frosty night also have some influence on the amount of damage.

If an attempt were made to name a critical temperature for fruit buds, blossoms, and immature fruits in different stages of development, even in a general way, it would be

necessary to describe the stage of advancement of the blossoms in greater detail than has been the rule in the past. The three classifications that have been used most generally heretofore are "showing pink," "full bloom," and "petals fallen." From experience in the Rogue River Valley, Bosc pear buds, just before the flowers open, are more easily injured by frost than two or three days later, when the flowers have opened fully. The buds appear to be more susceptible to injury in this stage than in any earlier or later stage.

The amount of damage to fruit buds, blossoms, and immature fruits caused by the low temperatures mentioned in this paper is considerably less than would have been expected based on the critical temperatures which have been generally accepted heretofore. It is recognized that the critical temperatures as determined by the data in the foregoing pages may not apply in other sections of the country. However, the relatively small amount of damage caused by low temperatures, as shown by the data in the preceding pages, can not be said to be exceptional in the case of the Rogue River Valley. The writers have been checking up on the damage to pear blossoms and fruits caused by spring frosts during the past six years, and all the data secured during this period strengthens the conclusion that the generally accepted critical temperatures for pears do not apply in this locality. No careful observations have been made in other fruit-growing communities on the Pacific coast, but interviews with County Horticultural Commissioners and fruit growers in some of the pear-growing sections of California would indicate that experience has been the same there.

Observations of low temperatures during frosts, and their effects on the size and general condition of the fruit crop immediately following the frost and at harvest time, were continued through the spring frost season of 1923. As these observations were made after this paper had been prepared for publication, only a brief reference to them will be made here, to show how they strengthen the conclusions to be drawn from data obtained in preceding years.

OBSERVATIONS DURING 1923 FROST SEASON.

The spring of 1923 was free from unusual weather conditions, and pear trees bloomed at about the average time. There were only a few heavy frosts, and damage was confined entirely to the colder orchards on the lower ground. The statements below show the duration of the low temperatures in several pear and apple orchards after the fruit had set. On April 22 pears were generally about the size of large peas, and by May 2, the date of the last frost of the season, they were about the size of the fruits shown in Figure 47.

Records were obtained in five different orchards, which will be designated by number. In each of these orchards the care of the trees was excellent in every particular. All orchards are irrigated.

Orchard No. 1.—Trees 14 years old; soil clay loam.

April 22–23, 1923.—Lowest temperature 28.3° F. Temperature below 32° F. 4 hours and 25 minutes. Bosc pears were almost uniformly frozen through, and every fruit contained a coating of ice, which could be peeled off, due to frozen dew. Every fruit within sight from ground showed this condition. Anjou pears were generally only partially frozen, probably due to the fact that the foliage on the Bartlett and Anjou trees was considerably heavier at this time than the foliage on the Bosc trees. Observations made about sunrise.

April 23–24, 1923.—Lowest temperature 29° F. Temperature below 32° F. two hours. Bosc, Bartlett, and Anjou pears again frozen, but not through to the core.

April 24–25, 1923.—Lowest temperature 29.2° F. Temperature below 32° F. 3 hours 25 minutes. Bosc, Bartlett, and Anjou pears again frozen, but not through to the core.

April 29–30, 1923.—Lowest temperature 28.7° F. Temperature below 32° F. 3 hours 30 minutes. Practically all fruit within sight from the ground frozen almost to the core. Many fruits badly mottled, but no blistering. Considerable cloudiness toward morning.

May 1–2, 1923.—Lowest temperature 28.2°. Temperature below 32° F. 3 hours 35 minutes. Observations made in afternoon of May 2nd. 95 per cent of the Bosc fruits in the lower portion of the trees have russet rings around their larger ends. About 50 per cent of the fruits show small longitudinal cracks. A very small percentage have slightly discolored seeds.

Anjou pears show a mottled effect quite generally, but no cracks or blisters.

Bartlett pears show general mottling, with some blistering.

Condition of fruit when harvested.—Heavy crop of Bartlett, Bosc, and Anjou pears harvested. About 30 per cent of the Bartlett pears in the lower portion of the trees were frost-marked, the portion of the fruits near the blossom end showing russet. There were practically no misshapen Bartlett pears on the trees.

Bosc pears showed no effects of the spring frosts, except an unusually high russet color, which is an asset to the Bosc.

Anjou pears in the lower portion of the trees showed no effect of the frosts.

Orchard No. 2.—Trees 17 years old. Soil clay loam.

April 22–23, 1923.—Lowest temperature 29.4° F. Temperature below 32° F. 4 hours 30 minutes. Observations made about sunrise. Most of Bosc and Anjou fruits showed freezing almost to the core, and in a few cases, through the core. A very few fruits showed small red spots on the skin. A few others showed a mottling of the skin, but these constituted only a very small percentage of the crop.

April 29–30, 1923.—Lowest temperature 28.3°. Temperature below 32° F. 3 hours 20 minutes. Observation about 15 minutes before sunrise. Anjou and Bosc pears within reach of the ground were almost uniformly frozen through, and about 10 per cent showed raised blisters on the skin.

May 1–2, 1923.—Lowest temperature 29.1° F. Temperature below 32° F. 3 hours 15 minutes. Observations made about sunrise, Bosc and Anjou fruits appeared to be badly frozen, particularly the Anjou. Some clusters were found with every pear frozen through and badly blistered and wrinkled.

Condition of fruit when harvested.—Anjou trees bore a heavy crop of pears, which were of exceptionally fine quality from every standpoint. No evidence of frost damage.

Bosc pear trees bore a heavy crop of fruit, most of which was packed in the extra fancy grade. No evidence of the effects of the spring frosts, except possibly in an unusually heavy russeting, which may or may not have been due to spring frosts.

Orchard No. 3.—Trees 17 years old. Soil clay loam.

April 22–23, 1923.—Lowest temperature 29.3°. Temperature below 32° F. 3 hours 30 minutes. Practically no indication of damage to Anjou pears. Observation about sunrise.

April 29–30, 1923.—Lowest temperature 28.5°. Temperature below 32° F. 3 hours 10 minutes. A large percentage of the Anjou fruits show indications of being frozen about half through, on the exposed sides. Some mottling, but no blistering.

May 1–2, 1923.—Lowest temperature 28.4° F. Temperature below 32° F. 3 hours 35 minutes. Anjou pears and Yellow Newtown apples were carefully examined about sunrise, but there was little indication of damage to either. The apples were about the size of large peas at this time. An occasional Anjou pear was found frozen through, but these were usually the smaller fruits in the clusters. A small percentage of the larger fruits showed frozen spots on the exposed sides, but the freezing did not extend very far into the pears. No blistering whatever was found here. The leaves were large and the foliage heavy, affording considerable protection to the fruit.

Condition of fruit when harvested.—No evidence of the effects of spring frosts on Anjou pears or Yellow Newtown apples.

Orchard No. 4.—Trees 21 years old. Soil sandy loam.

April 22–23, 1923.—Lowest temperature 30.3° F. Temperature below 32° F. 2 hours 25 minutes. No damage to Bosc or Comice pears.

April 29–30, 1923.—Lowest temperature 30° F. No damage.

May 1–2, 1923.—Lowest temperature 28.2° F. Temperature below 32° 3 hours 20 minutes. Observations made on the afternoon of May 2. No sign of injury to the interior of Bosc or Comice pears was found. Bosc fruits, which were exceptionally large in this orchard, showed almost without exception a rather heavy mottling of the skins, but no blistering was found. Comice fruits showed no sign of damage, except for an occasional fruit which showed some slight blistering.

Condition of fruit when harvested.—Heavy crop of both Bosc and Comice pears harvested, with no sign of frost injury to either variety.

Orchard No. 5.—Trees 20 years old. Soil clay adobe.

April 29–30, 1923.—Lowest temperature 28° F. Temperature below 32° F. 4 hours 15 minutes. No indication of damage to Yellow Newtown apples, about the size of small peas.

May 1–2, 1923.—Lowest temperature 27.4° F. Temperature below 32° F. four hours. No indication of damage to exterior of Yellow Newtown apples. About 2 per cent of fruits showed a slight discoloration of the seeds.

Condition of fruit when harvested.—Apple trees were heavily thinned late in May. The final crop of fruit was of high grade and showed no evidence of frost injury.

Most growers of deciduous fruit are rather sensitive on the subject of damage to their crops by frost and prefer to attribute a light crop to almost any other agency than frost damage. "Lack of pollination" is named as the cause of a short crop, when if there had been no frost there would have been no lack of pollination. Figures 39 and 40 show the difference in the appearance of two Howell pear branches about three weeks after full bloom. The blossoms on the branch from an unprotected orchard have made practically no growth since they were injured by frost and are rapidly falling to the ground. The branch from the orchard protected from damage through the use of orchard heaters contains many rapidly growing, vigorous fruits.

PRACTICAL RESULTS OF ORCHARD HEATING.

The different temperature diagrams in the preceding pages of this article show the results obtained on different nights in raising the temperature under actual orchard conditions, with temperatures prevailing outside the fired orchard which would cause damage to the crop. These records were obtained at several different locations in the Rogue River Valley. Five-quart and 2-gallon lard-pail oil heaters and high-stack, 5-gallon capacity oil heaters were used in different orchards.

In every case the thermometers were placed as far from the heaters as possible, and as a general rule the heaters nearest the temperature stations were not lighted.

From an examination of these records it will be seen that it is much easier to raise the temperature on some nights than on others, but on no night during the three seasons covered by these records was there any difficulty in maintaining the temperature above the danger point, using only a fraction of the total number of heaters available.

These records show that it is possible to raise the temperature as much as 8° under exceptionally favorable conditions. However, the average rise in temperature secured with orchard heaters is about 5°. Due to the fact that the layer of cold air near the ground is generally quite thin in the colder locations in a valley, the temperature usually can be raised a greater number of degrees with the same number of heaters at such locations, than in warmer spots on high ground, where the increase in air temperature with elevation is less.

ORCHARD HEATING DURING THE 1921 SEASON.

During the 1921 season the exceptionally severe spring frosts caused such widespread damage to pear crops, an unusual opportunity to note the direct effect of orchard heating on the final crops of fruit was offered. Comparisons between the total amount of fruit harvested in adjoining orchards, protected and unprotected, are given in the following paragraphs:

The greatest damage during the season occurred on the night of April 3–4. A description of the weather on these dates has been given on a preceding page, and temperature records at two locations are shown in figures 12 and 18.

The only 100 per cent crops of pears harvested in the valley in 1921 were those from orchards which were protected with orchard heaters on this night. In order to show that the reduction in tonnage from unprotected orchards was due to frost damage, one of the orchards that were protected with orchard heaters on every cold night during both the 1921 and 1922 seasons will be used as a check. Figure 41 shows the heavy crop of Bosc pears harvested in this orchard during the 1921 season, and figures 42 and 43 show the size of the crop harvested in 1922. The crop was somewhat larger in 1922, but a part of this increase was undoubtedly due to the fact that the orchard was irrigated during the 1922 season for the first time.

A heavy crop of Bosc pears was harvested in 1921 at another orchard, in a very cold locality, which was well protected with orchard heaters.

COMPARISON BETWEEN CROPS IN PROTECTED AND UNPROTECTED ORCHARDS.

Case 1.—A large pear orchard was divided into two smaller orchards and sold to two different individuals in 1920. The owner of one of these divisions protected his trees with orchard heaters in a very efficient and thorough manner. The owner of the other division had all the necessary orchard heating equipment on hand but decided to "take a chance." The type of soil and the care of the trees was the same in both orchards

The orchard equipped with orchard heaters was not protected on the first cold night, April 3–4, and there was heavy damage to blossoms.

Anjou.—Figures 44 and 45 show the size of the crop of Anjou pears in the fired orchard, while Figure 46 shows the average crop harvested in the unprotected orchard.

Bartlett.—The relative size of the crops of Bartlett pears in the protected and unprotected orchards is shown in figures 47 and 48. The fruit in the unprotected orchard was practically all frost marked, while there was practically no marked fruit in the protected orchard.

Bosc.—Sixteen-year-old Bosc trees in the unprotected orchard bore less than 15 per cent of a full crop in 1921, but as there were no protected Bosc trees in the vicinity, it was not possible to make a comparison. However, the owner of this orchard used his orchard heaters to good advantage during the 1922 season, and harvested one of the best crops of Bosc pears in the valley. (See fig. 54.)

Case 2.—Two orchards a short distance apart had been protected with orchard heaters for several years. In 1921 the owner of the higher and warmer of these two decided not to use his heating equipment and did not set the heaters in the orchard. His loss was one of the most severe in the entire valley.

Howell.—On April 12, 1921, a careful check was made on the block of Howell trees nearest the fired orchard, which showed that 98 per cent of the blossoms had been killed by frost up to this time.

The average crop of fruit harvested in this block was estimated at 3 per cent of a full crop. Figures 49 and 50 show the comparative average yields of Howell pears in the protected and unprotected orchards. The heaters in the protected orchard were not lighted on the coldest night of the season, April 3–4, and considerable damage was done. If the heaters had been fired heavily on this night, the difference between the crops in the two orchards undoubtedly would have been much greater.

To show that the normal yield of the trees in the unprotected orchard is large, the average crop secured from the same trees in 1922, when the orchard was protected with orchard heaters and there was little frost to combat, is shown in Figure 51.

Bosc.—A careful check of the Bosc block nearest the protected orchard on April 6, 1921, showed that 45 per cent of the blossoms had been killed. On April 12 scarcely an uninjured blossom could be found.

At the end of the season these trees were practically bare of fruit. Many trees did not bear even one fruit. The average crop harvested from this block was estimated at 2 per cent of a normal crop. There were no protected Bosc trees near by which could be used as a check, but an orchard in a much lower and colder portion of the valley, which was protected with orchard heaters, bore an exceptionally heavy crop of Bosc.

The average crop of pears borne by the same trees which were practically bare of fruit in 1921, is shown in Figure 52.

1922 SEASON.

As has been stated previously, there was very little frost during the 1922 season, and serious damage was confined to the lower and colder spots. The unfired orchard mentioned in case 1, of the 1921 season, is in a very cold location. During the 1922 season the owner, profiting by his experience in 1921, set out the heaviest battery of orchard heaters in the valley. His temperature records, together with those at a neighboring unprotected orchard used as a check on the outside temperature, are shown in Figure 23.

On the night of April 27–28, 1922 (see fig. 23), the blossoms on a 12-year-old Bosc tree at the check station were practically all killed. At the end of the season this tree carried only two pears. Figure 53 is a photograph of a Bosc tree of the same age and size in the heated orchard, showing the heavy crop of fruit. The crop on this tree was representative of the average crop on all trees of like size in the heated orchard.

The average amount of fruit picked from the older Bosc trees in the heated orchard in 1922 is shown in Figure 54. All the trees were breaking down with fruit and could not have matured a heavier crop.

Differences between fruit crops in protected and unprotected orchards were not so great in 1922 on higher ground, but in many instances there was a great difference between the grades of Bartlett pears in fired and unfired orchards. In some unprotected orchards more than 50 per cent of the Bartlett fruits were badly frost marked and misshapen, while in adjoining heated orchards the quantity of marked fruit was negligible.

CONCLUSION.

The effectiveness of the orchard heater, when used properly and in sufficient numbers, in preventing damage to fruit by frost in the Rogue River Valley is no longer open to question. It is possible that extreme cold, accompanied by strong winds, may occur at some future time, and it is possible that orchard heaters may not prove effective in such a case, but from all available weather records it appears that such nights do not occur often.

While all the observations on which this paper is based were made in the Rogue River Valley, it is believed the conclusions regarding the effectiveness of orchard heating, when properly handled, in preventing damage by frost apply with equal force to all the deciduous fruit-growing valleys in western Oregon and in the entire States of California and Washington. Careful study of the matter in the field, outside of the Rogue River Valley, has been confined to the Yakima Valley, in the State of Washington, and the Sacramento and Santa Clara Valleys, in California. Detailed orchard-heating studies also have been made in the citrus districts of southern California. Records secured during the freezes of January and February, 1922, in southern California demonstrated conclusively that orange groves can be protected against outside temperatures of 18° F. by orchard heating, and the protective value of heating is now generally accepted by citrus growers throughout the State.

It is interesting to note that one of the largest pear and apple orchards in the Rogue River Valley has been using orchard heaters during the past 13 years. During that time the fruit crop never has been materially reduced through frost damage, notwithstanding the fact that the orchard is located in one of the coldest spots in the valley.

Until about 1914 fruit growers were attempting to burn heavy crude oil, as it comes from the wells, in the orchard heaters, with the result that the heaters soon filled with unconsumed asphaltum, or the water content of the oil was so high that the heaters boiled over or exploded soon after lighting. At the present time all the larger oil corporations on the Pacific coast are furnishing a special orchard heater oil, from which most of the asphaltum

FIG. 47.—Average yield of Bartlett pears per tree in 1921 in orchard which was protected from frost damage with lard-pail orchard heaters. The fruit shown in this photograph was carefully examined, and only two pears in the lot showed frost marks. Compare with Figure 48. Out of the first 188 boxes of Bartlett pears picked in this orchard 144 graded extra fancy and 42 graded fancy, with only 2 boxes of culls.

FIG. 48.—Average yield per tree of Bartlett pears in unprotected orchard adjoining that shown in Figure 47 during the 1921 season. More than two-thirds of the crop was so badly frost marked that it was unmarketable as fresh fruit.

FIG. 49.—Average yield per tree of Howell pears in 1921 in orchard which was protected from damage by frost with lard-pail orchard heaters. The heaters in this orchard were not lighted on the first cold night of the season, when the temperature fell extremely low, and a large percentage of the blossoms were killed. The crop probably would have been considerably larger if the trees had been protected on this night. Compare with Figure 50.

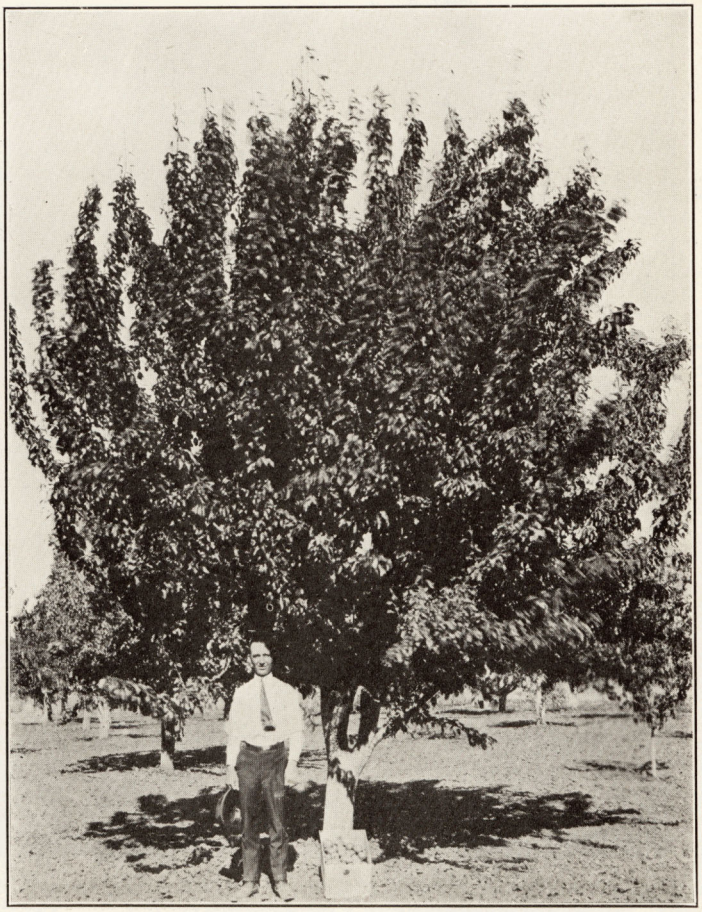

FIG. 50.—Average yield per tree of Howell pears in 1921 in unprotected orchard near that shown in Figure 49. The protected orchard was in a lower and somewhat colder location than the unprotected orchard.

(To face p. 639.)

FIG. 51.—Average yield per tree of Howell pears in 1922 in orchard shown in Figure 50. This orchard was protected from damage by frost with lard-pail orchard heaters during the 1922 frost season.

FIG. 52.—Average yield per tree of Bosc pears in 1922 in orchard shown in Figures 50 and 51. Trees were protected in 1922 with lard-pail orchard heaters. Crop from these trees in 1921, when unprotected from frost, averaged less than one-third box per tree, and many trees were absolutely bare of fruit.

FIG. 53.—Young Bosc pear tree (12 years old) in orchard protected with lard-pail orchard heaters in 1922, showing heavy crop of fruit. Bosc tree of same age in adjoining orchard matured only two pears.

FIG. 54.—Average yield of Bosc pears per tree in orchard in cold location protected with lard-pail orchard heaters, season of 1922.

and water have been removed. Since the early days of orchard heating new heaters have been developed, and the growers have equipped themselves with better thermometers; they understand the principles of orchard heating better and are better organized to properly handle the frost fighting.

No thorough, careful tests of the effectiveness of orchard heating under the weather conditions which accompany damaging temperatures during the blossoming period of deciduous fruits in the eastern portion of the United States have been made, so far as the writers are aware. Whether orchard heating will prove to be consistently successful in that portion of the country is highly problematical.

ECONOMIC PHASE OF ORCHARD HEATING.

The writers have confined the discussion of orchard heating in this paper to the question of the practicability of protecting deciduous buds, blossoms, and fruits from damage by spring frosts. The economic side of the question has been purposely ignored, and it will only be touched upon here.

The costs of orchard heating equipment, fuel, etc., vary in different parts of the country, as do the temperatures experienced and the weather conditions which accompany damaging frosts. The grade of fruit produced and prices received for the crops also vary, not only in different districts but in different orchards in the same district.

Obviously, whether orchard heating will pay in a certain orchard will depend on the amount of monetary loss by frost over a period of years and the total cost of protective operations over the same period, including interest on investment, depreciation charge on equipment, and cost of fuel and labor. If the net profit on a crop were the only consideration in determining whether frost protection will pay, the answer would be negative for most if not all the fruit districts of the country. However, when an entire fruit crop is destroyed by frost, the owner's loss is not confined to the net profit he would have made on the crop; the expense of caring for the orchard for a year, interest on the money invested in the orchard, and other similar expenses must be added.

The amount of the loss, therefore, generally speaking, will be the gross value of the crop less the expenses of picking, packing, etc. The loss calculated on this basis is often very large. Many instances have come to the attention of the writers of fruit growers who have saved enough fruit in a single season, or even on a single frosty night, to pay the total cost of equipping the orchard with heaters and auxiliary equipment, together with the expenses of protecting the orchard during the season.

In other words, orchard heating can not be considered on the same basis as fire insurance. Answering a writer who had endeavored to show that orchard heating was unsound from a business standpoint, because the cost was prohibitive when compared to the cost of fire insurance, one of the most successful growers of citrus fruits in California, who has used orchard heaters during the past 12 years, called attention to the fact that if a man was reasonably sure that his house would burn down at least once every 10 years, he would be willing to pay a high premium for insurance.

Another point that must be considered is the fact that whenever a general freeze destroys a large portion of the total crop of a certain fruit, the resulting shortage usually causes higher prices. In such years successful orchard heating usually yields a high return. In many cases this is the factor which makes orchard heating profitable.

The orchards in the United States that sustain sufficient damage by frost to justify the use of orchard heating equipment make up only a very small percentage of the total acreage in fruit trees. Even in the Pacific Coast States orchard heating is generally practiced only in the colder portions of each district.

MOUNTAIN SNOWFALL AND FLOOD CRESTS IN THE COLORADO.

By J. M. SHERIER.

[Weather Bureau, Denver, Colo., Sept. 19, 1923.]

In some respects the situation along the lower Colorado resembles that in the Nile Valley. In addition to the similarity of the soil, climate, and products, a certain amount of water is required each year for irrigation purposes, upon which growing crops are almost wholly dependent and without which there would be a desert. On the other hand, any flood of proportions sufficient to overtop or to break through the principal levees would cause enormous financial loss and endanger many lives. It is not surprising, therefore, that the apprehension felt in western Arizona and southeastern California begins to manifest itself toward the close of every winter in letters and telegrams to the district forecast center, requesting information as to the accumulations of snow in the upper portion of the drainage area, together with the opinion of the forecaster in regard to the prospects of dangerously high water during the following late spring and early summer.

For forecasting purposes, the Colorado drainage area is made up of three divisions. The lower division extends from the mouth of the main stream to Boulder Canyon; the middle division from Boulder Canyon to gaging stations at Elgin, on the Green; Fruita, on the Colorado; and Farmington, on the San Juan. As flood crests due to run-off from the middle division occur early in the season and are not high enough to cause serious trouble, they have not been considered in this discussion.

It must be apparent to all who have had experience in the forecasting of floods that crests produced by melting snow depend not only upon the accumulation of snowfall at the end of the cold season, but also upon the rate at which it is melted and finds its way into the river. In other words, a moderate accumulation in the mountains may disappear so quickly, due to protracted high temperatures, as to cause alarmingly high stages, while unusual amounts of snow at the higher elevations may be taken off by a number of warm periods of only a few days' duration each, followed by weather cool enough to check or to stop the consequent melting. Under the latter conditions, a series of flood crests would result, the highest of which might not be sufficient to cause much alarm. It is not intended to minimize the danger of excessive snow accumulations in the mountains of the upper drainage area at the beginning of spring, but rather to emphasize the fact that the height of subsequent